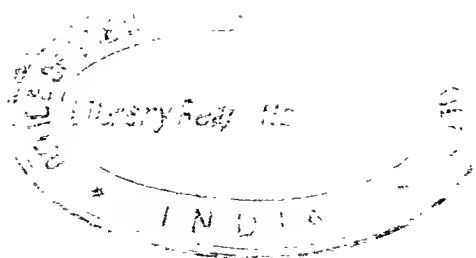


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ANNUAL REPORT OF THE
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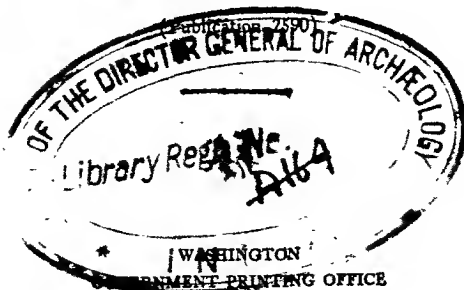
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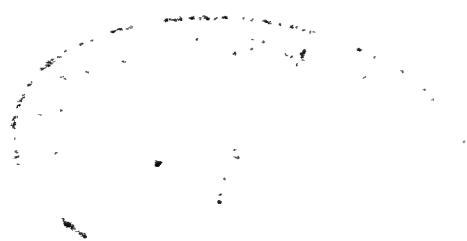
OPERATIONS, EXPENDITURES, AND
CONDITION OF THE INSTITUTION
FOR THE YEAR ENDING JUNE 30

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LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

SUBMITTING

THE ANNUAL REPORT OF THE BOARD OF REGENTS OF THE
INSTITUTION FOR THE YEAR ENDING JUNE 30, 1919.

SMITHSONIAN INSTITUTION,
Washington, September 24, 1920.

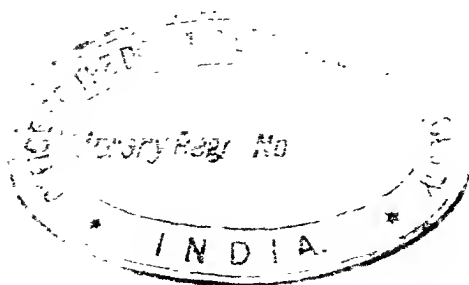
To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ending June 30, 1919. I have the honor to be,

Very respectfully, your obedient servant,

W. DE C. RAVENEL,
Acting Secretary.

III



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**ANNUAL REPORT OF THE BOARD OF REGENTS OF THE SMITHSONIAN
INSTITUTION FOR THE YEAR ENDING JUNE 30, 1919.**

SUBJECTS.

1. Annual report of the secretary, giving an account of the operations and condition of the Institution for the year ending June 30, 1919, with statistics of exchanges, etc.

2. Report of the executive committee of the Board of Regents, exhibiting the financial affairs of the Institution, including a statement of the Smithsonian fund, and receipts and expenditures for the year ending June 30, 1919.

3. Proceedings of the Board of Regents for the fiscal year ending June 30, 1919.

4. General appendix, comprising a selection of miscellaneous memoirs of interest to collaborators and correspondents of the Institution, teachers, and others engaged in the promotion of knowledge. These memoirs relate chiefly to the calendar year 1919.

THE SMITHSONIAN INSTITUTION.

June 30, 1919.

Presiding officer ex officio.—WOODROW WILSON, President of the United States.

Chancellor.—EDWARD DOUGLASS WHITE, Chief Justice of the United States.

Members of the Institution:

WOODROW WILSON, President of the United States.

THOMAS R. MARSHALL, Vice President of the United States.

EDWARD DOUGLASS WHITE, Chief Justice of the United States.

ROBERT LANSING, Secretary of State.

CARTER GLASS, Secretary of the Treasury.

NEWTON DIEHL BAKER, Secretary of War.

A. MITCHELL PALMER, Attorney General.

ALBERT SIDNEY BURLESON, Postmaster General.

JOSEPHUS DANIELS, Secretary of the Navy.

FRANKLIN KNIGHT LANE, Secretary of the Interior.

DAVID FRANKLIN HOUSTON, Secretary of Agriculture.

WILLIAM COX REDFIELD, Secretary of Commerce.

WILLIAM BAUCHOP WILSON, Secretary of Labor.

Regents of the Institution:

EDWARD DOUGLASS WHITE, Chief Justice of the United States, Chancellor.

THOMAS R. MARSHALL, Vice President of the United States.

HENRY CABOT LODGE, Member of the Senate.

CHARLES S. THOMAS, Member of the Senate.

SCOTT FERRIS, Member of the House of Representatives.

LEMUEL P. PADGETT, Member of the House of Representatives.

FRANK L. GREENE, Member of the House of Representatives.

ALEXANDER GRAHAM BELL, citizen of Washington, D. C.

GEORGE GRAY, citizen of Delaware.

CHARLES F. CHOATE, Jr., citizen of Massachusetts.

JOHN B. HENDERSON, citizen of Washington, D. C.

HENRY WHITE, citizen of Maryland.

ROBERT S. BROOKINGS, citizen of Missouri.

Executive committee.—GEORGE GRAY, ALEXANDER GRAHAM BELL, HENRY WHITE.

Secretary of the Institution.—CHARLES D. WALCOTT.

Assistant Secretary.—C. G. ABBOT.

Chief Clerk.—HARRY W. DORSEY.

Accounting and disbursing agent.—W. I. ADAMS.

Editor.—W. P. TRUE.

Assistant librarian.—PAUL BROCKETT.

Property clerk.—J. H. HILL.

THE NATIONAL MUSEUM.

Keeper ex officio.—CHARLES D. WALCOTT, Secretary of the Smithsonian Institution.

Administrative assistant to the Secretary, in charge.—W. DE C. RAVENEL.

Head curators.—WILLIAM H. HOLMES, LEONHARD STEJNEGER, G. P. MERRILL.

Curators.—PAUL BARTSCH, R. S. BASSLER, T. T. BELOTE, F. W. CLARKE, F. V. COVILLE, W. H. DALL, CHESTER G. GILBERT, WALTER HOUGH, L. O. HOWARD, ALEŠ HEDLIČKA, NEIL M. JUDD, FREDERICK L. LEWTON, GERRIT S. MILLER, Jr., JOSEPH E. POGUE, ROBERT RIDGWAY.

Associate curators.—J. M. ALDRICH, J. C. CRAWFORD, C. W. GILMORE, W. R. MAXON, CHARLES W. RICHMOND, J. N. ROSE, DAVID WHITE.

Curator, National Gallery of Art.—W. H. HOLMES.

Chief of correspondence and documents.—H. S. BRYANT.

Disbursing agent.—W. I. ADAMS.

Superintendent of buildings and labor.—J. S. GOLDSMITH.

Editor.—MARCUS BENJAMIN.

Assistant librarian.—N. P. SCUDDER.

Photographer.—L. W. BEESON.

Registrar.—S. C. BROWN.

Property clerk.—W. A. KNOWLES.

Engineer.—C. R. DENMARK.

BUREAU OF AMERICAN ETHNOLOGY.

Chief.—J. WALTER FEWKES.

Ethnologists.—JOHN P. HARRINGTON, J. N. B. HEWITT, FRANCIS LA FLESCHÉ, TRUMAN MICHELSON, JAMES MOONEY, JOHN R. SWANTON.

Honorary philologist.—FRANZ BOAS.

Editor.—STANLEY SEARLES.

Librarian.—ELLA LEARY.

Illustrator.—DE LANCEY GILL.

INTERNATIONAL EXCHANGES.

Chief clerk.—C. W. SHOEMAKER.

NATIONAL ZOOLOGICAL PARK.

Superintendent.—NED HOLLISTER.

Assistant Superintendent.—A. B. BAKER.

ASTROPHYSICAL OBSERVATORY.

Director.—C. G. ABBOT.

Aid.—F. E. FOWLE, Jr.

Assistant.—L. B. ALDRICH.

REGIONAL BUREAU FOR THE UNITED STATES, INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

Assistant in charge.—LEONARD C. GUNNELL.

REPORT
OF THE
SECRETARY OF THE SMITHSONIAN INSTITUTION

CHARLES D. WALCOTT,
FOR THE YEAR ENDING JUNE 30, 1919

To the Board of Regents of the Smithsonian Institution.

GENTLEMEN: I have the honor to submit herewith an annual report on the activities and condition of the Smithsonian Institution and its branches during the year ending June 30, 1919. The activities of the Institution proper are reviewed in the first part of the report, together with a brief summary of the affairs of each of the several branches. In the appendices will be found more detailed accounts of the work of the National Museum, the Bureau of American Ethnology, the International Exchange Service, the National Zoological Park, the Astrophysical Observatory, the Smithsonian Library, the International Catalogue of Scientific Literature, and an account of the publications of the Institution and its branches. The reports of the Museum and Bureau of Ethnology are published in greater detail in separate volumes.

THE SMITHSONIAN INSTITUTION.

THE ESTABLISHMENT.

The Smithsonian Institution was created by act of Congress, in 1846, according to the terms of the will of James Smithson, of England, who in 1826 bequeathed his property to the United States of America "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." In receiving the property and accepting the trust Congress determined that the Federal Government was without authority to administer the trust directly, and therefore constituted an "establishment," whose statutory members are "the President, the Vice President, the Chief Justice, and the heads of the executive departments."

THE BOARD OF REGENTS.

The business of the Institution is conducted by a Board of Regents composed of "the Vice President, the Chief Justice of the United States, and three Members of the Senate, and three Members of the

House of Representatives, together with six other persons other than Members of Congress, two of whom shall be resident in the city of Washington and the other four shall be inhabitants of some State, but no two of them of the same State." The regents elect one of their number as chancellor, usually the Chief Justice, who is the presiding officer of the board, and elect a suitable person as secretary of the Institution, who is also secretary of the board and the executive officer and director of the Institution's activities.

The changes in personnel of the board during the year were the appointment of George Gray, citizen of Delaware, to succeed himself; the appointment of Robert S. Brookings, citizen of Missouri, to fill the vacancy caused by the death of Charles W. Fairbanks. The roll of regents on June 30, 1919, was as follows: Edward D. White, Chief Justice of the United States, chancellor; Thomas R. Marshall, Vice President of the United States; Henry Cabot Lodge, Member of the Senate; Charles S. Thomas, Member of the Senate; Scott Ferris, Member of the House of Representatives; Lemuel P. Padgett, Member of the House of Representatives; Frank L. Greene, Member of the House of Representatives; Alexander Graham Bell, citizen of Washington, D. C.; George Gray, citizen of Delaware; Charles F. Choate, jr., citizen of Massachusetts; John B. Henderson, citizen of Washington, D. C.; Henry White, citizen of Maryland; and Robert S. Brookings, citizen of Missouri.

The board held its annual meeting on December 12, 1918. The proceedings of that meeting, as also the annual financial report of the executive committee, have been printed, as usual, for the use of the regents, while such important matters acted upon as are of public interest are reviewed under appropriate heads in the report of the secretary. A detailed statement of disbursements from the Government appropriations under the direction of the Institution for the maintenance of the National Museum, the National Zoological Park, and other branches will be submitted to Congress by the secretary in the usual manner in compliance with the law.

GENERAL CONSIDERATIONS.

In addition to the usual activities and routine duties, the scientific staff of the Institution continued, until the day of the signing of the armistice, to assist the Government in every way possible toward the successful prosecution of the war. The Museum staff were in constant touch with Army and Navy officials, furnishing much technical information, and the staff of the Astrophysical Observatory conducted numerous valuable researches. Mr. L. B. Aldrich, of the observatory, carried out successful experiments on the pressure exerted by the wind upon projectiles, at the request of the Coast Artillery Station at Fortress Monroe. Assistant Secretary Abbot and Mr.

Aldrich together worked on the problem of searchlights for Army use, and, after numerous experiments, they were able to improve the existing searchlights, both by diminution of size and increase in lighting power. The new form of searchlight was constructed and used in France several months before the close of hostilities.

At the time of the signing of the armistice several valuable devices were being perfected by Dr. Abbot and the observatory staff, among them a recoilless gun devised by Dr. R. H. Goddard, of Clark College, which was a development of work being done by him for the Institution on a multiple-charge rocket intended to reach great heights for meteorological observations; an instrument for determining geographical positions from an airplane or a ship at sea without reference to landmarks, whether celestial or terrestrial; and a rotating projectile constructed on the turbine principle to be fired from a smoothbore gun, which would have been specially valuable for use in trench mortars.

On December 16, 1918, Dr. C. G. Abbot, Director of the Astrophysical Observatory, was appointed assistant secretary of the Institution to fill the vacancy caused by the death of Dr. F. W. True some years ago. In addition to his administrative duties in connection with the Institution, Dr. Abbot will be in charge of the Smithsonian Library, the International Exchange Service, and the Astrophysical Observatory.

The work of the National Research Council, of which your secretary was first vice chairman, was continued under the war organization during the first part of the year. After the signing of the armistice every effort was concentrated on the organization of the council upon a peace basis, and this was accomplished very successfully before the close of the year under a definite plan in accordance with an Executive order from the President of the United States requesting the National Academy of Sciences to perpetuate the National Research Council.

The secretary of the Institution was also chairman of the executive committee of the national advisory committee for aeronautics, which performed work of great value to the Government on airplane production and improvements.

An important peace-time event was the organizing just before the close of the year of an extensive exploring expedition to the heart of Africa. The material collected will come to the Institution to be used for purposes of comparison in working up the results of various expeditions to the Dark Continent by Col. Roosevelt, Paul Rainey, and others.

Bequests.—An important bequest was made to the Institution during the year by Mrs. Virginia Purdy Bacon, of New York, which will do much toward extending our knowledge of the fauna of the

world. That portion of Mrs. Bacon's will relating to the Institution reads as follows:

(f) To Smithsonian Institute the sum of fifty thousand dollars (\$50,000), to be used in establishing a traveling scholarship, to be called the Walter Rathbone Bacon Scholarship for the study of the fauna of countries other than the United States of America; the incumbents to be designated by said Institute under such regulations as it may from time to time prescribe and to hold such scholarships not less than two years, and while holding such scholarship to conduct for said Institute investigations in the fauna of other countries under the direction of said Institute.

The terms of the will had not been executed at the close of the year.

FINANCES.

The invested funds of the Institution are as follows:

Deposited in the Treasury of the United States under authority of Congress..... \$1,000,000.00

CONSOLIDATED FUND.

Brooklyn Rapid Transit 5 per cent notes, due July 1, 1918.....	3,528.44
American Telephone & Telegraph Co. 4 per cent collateral trust bonds, due July 1, 1929.....	15,680.00
Province of Manitoba 5 per cent gold debentures, due Apr. 1, 1922..	1,935.00
West Shore Railroad Co. guaranteed 4 per cent first mortgage bonds, due Jan. 1, 1931.....	37,275.00
Cleveland Electric Illuminating Co. first mortgage 5 per cent gold bonds, due 1939.....	5,670.00
United States first Liberty loan.....	200.00
United States second Liberty loan.....	100.00
United States third Liberty loan.....	10,150.00
United States fourth Liberty loan.....	50.00
United States war-savings stamps, series of 1918.....	100.00
Adjustments	105.94
Total	1,074,794.38

The sum invested for each specific fund and the manner in which the several investments were made is given in the following statement:

	United States Treasury.	Consolidated fund.	Total.
Smithson fund.....	\$727,640.00	\$984.00	\$728,624.00
Habel fund.....	500.00		500.00
Hamilton fund.....	2,500.00		2,500.00
Hodgkins general fund.....	116,000.00	37,275.00	153,275.00
Hodgkins specific fund.....	100,000.00		100,000.00
Rhees fund.....	590.00	74.00	664.00
Avery fund.....	14,000.00	14,824.45	28,824.45
Addison T. Reid fund.....	11,000.00	1,348.00	12,348.00
Lucy T. and George W. Poore fund.....	26,670.00	2,819.00	29,489.00
George K. Sanford fund.....	1,100.00	142.00	1,242.00
Chamberlain fund.....		10,000.00	10,000.00
Bruce Hughes fund.....		7,327.93	7,327.93
Total.....	1,000,000.00	74,794.38	1,074,794.38

The Brooklyn Rapid Transit Co. was placed in the hands of receivers on July 1, 1918.

For the \$5,000 in 5 per cent gold notes which failed of redemption on the above date, \$1,500 was subsequently paid to the Institution in cash and the balance of \$3,500 is held by the receivers pending final adjustment.

A single piece of real estate bequeathed to the Institution by the late Robert Stanton Avery, and located in the District of Columbia, 326 A Street SE., was sold and the sum of \$3,046.50 was realized therefrom. Several lots of unimproved land located near Lowell, Mass., and forming a part of the bequest known as the Lucy T. and George W. Poore fund, were also sold and the sum of \$520.50 was realized, making a total of \$3,567 derived from the sale of real estate during the year.

Income not required for current expenditures continues to be placed with local banks on time deposit; the interest so earned during the year amounted to \$1,048.10.

The income of the institution during the year, amounting to \$144,100.53, was derived as follows: Interest on permanent investments and other sources, \$64,466.94; repayments, rentals, publications, etc., \$34,723.33; contributions from various sources for specific purposes, \$26,343.26; bills receivable, \$15,000; proceeds from sale of real estate, \$3,567.

Adding the cash balance of \$1,289.90 on July 1, 1918, the total resources for the year amounted to \$145,390.43.

Mr. B. H. Swales, honorary custodian, section of birds' eggs, has contributed \$300 to the Institution for the purchase of specimens.

The disbursements which are described in the annual report of the executive committee amounted to \$143,267.65, leaving a balance, on deposit with the Treasurer of the United States, in cash, and in bank, of \$2,122.78.

The Institution was charged by Congress with the disbursement of the following appropriations for the year ending June 30, 1919:

International exchanges.....	\$35,000
American ethnology.....	42,000
International catalogue of scientific literature.....	7,500
Astrophysical observatory.....	13,000
National Museum.....	
Furniture and fixtures.....	15,000
Heating and lighting.....	55,000
Preservation of collections.....	300,000
Building repairs.....	10,000
Books.....	2,000
Postage.....	500
National Zoological Park.....	115,000
Increase of compensation (indefinite).....	

Total..... 595,000

In addition to the above, there was included under the general appropriation for printing and binding an allotment of \$76,200, to cover the cost of printing and binding the Smithsonian annual report and reports and miscellaneous printing for the Government branches of the Institution.

RESEARCHES AND EXPLORATIONS.

The institution every year sends out or cooperates in expeditions to various parts of the world for the purpose of gathering all the information possible on the inhabitants, the fauna and flora, and other features of little-known regions, and thus carries out one of its primary objects—"the increase of knowledge." While the war conditions prevailing during the first half of the year blocked certain projects, several expeditions of importance to science were undertaken, and a few of these are briefly summarized here. The annual Exploration Pamphlet issued by the institution and the reports of the various branches describe these and other researches more in detail.

GEOLOGICAL EXPLORATIONS IN THE CANADIAN ROCKIES.

The geological explorations which have been conducted in the Canadian Rockies by your secretary for a number of years were continued during the summer season of 1918, chiefly for the purpose of determining the geological structure of the upper Bow Valley north of Lake Louise, Alberta, and also at the headwaters of the Cascade River, at Sawback Lake. Another aim of the investigation was to locate any possible occurrences of unusual beds of fossils in the regions visited.

Leaving the Canadian Pacific Railway at Lake Louise Station, the Bow Valley extends to the northwest parallel to the Continental Divide, which forms its southwestern side. Bow Lake at the head of the valley is a beautiful sheet of water hemmed in by bald mountain slopes and cliffs on the west and north and by the mass of Mount Molar on the east. From the west numerous glaciers drain into the lake. The first one encountered is Crowfoot, which flows from the great Wauputek snow field along the Continental Divide.

Bow Pass, 4 miles north of the head of Bow Lake, has been eroded by glacial action into a broad, park-like area, so that the passage over into the valley of the Mistaya River of the Saskatchewan River drainage is scarcely realized until steep slopes indicate the approach toward Lake Peyto. This beautiful lake, with a glacier at its head, drains into the Mistaya River. The bold escarpment on the north side of the lake is continued to the north down the Mistaya River to the Saskatchewan. Several sections were examined along this front,

which were found to be similar to the section at the head of Bow Lake.

The broad canyon valleys that unite the headwaters of the Saskatchewan River are all carved by erosion out of the same type of Cambrian rocks as those exposed in the vicinity of Bow Lake, and also in the Bow Valley south of Lake Louise Station.

At the close of the season a fine pair of mountain sheep, a black bear, one mule deer, a mountain goat, and a wolverine were collected, the skins and skulls being shipped to the National Museum.

GEOLOGICAL WORK IN THE MIDDLE ATLANTIC STATES.

During the field season of 1918 the members of the geological staff were chiefly occupied in collecting material for the museum exhibition series, most of the work being done in Virginia, Maryland, New Jersey, Pennsylvania, and New York. Sufficient material illustrating the weathering and decay of rocks was obtained by Dr. J. C. Martin, assistant curator of geology, United States National Museum, to make up 100 sets for distribution to those agricultural and other colleges which give instruction in rock weathering and soil formation. Dr. Martin also visited several localities in Pennsylvania, New Jersey, and New York for the purpose of filling certain gaps in the ore and rock collections.

In continuance of the search begun in recent years for large exhibition museum specimens to illustrate the various phases of structural geology and stratigraphic paleontology, Drs. Bassler and Resser, of the division of paleontology, report as follows:

Field work was begun with an investigation of the Cretaceous rocks of western New Jersey, where the prime object was to secure suitable exhibits of such economically important rocks of organic origin as glauconite, or greensand, and calcareous marl. The greensand area in the vicinity of Vincentown, N. J., afforded the best results in fossil and rock specimens for both study and exhibition. The very incoherent greensand could not be obtained in masses of a size suitable for exhibition, but by use of shellac a large piece was hardened sufficiently to be shipped to Washington without breakage. In the marl pits unusually well-preserved fossils were found scattered through an unconsolidated sand formation. Here specimens abound literally by the millions, and large numbers were collected by passing quantiles of the sand through a fine-meshed sieve, the residue in this process usually consisting of nothing but well-preserved fossils.

They then proceeded to the Lancaster Valley of Pennsylvania, where they were fortunate enough to secure intact a large mass of finely banded, crinkled limestone. This illustrates, on a small scale, the folding to which the earth's crust has been subjected, and forms a much-needed addition to the exhibits.

On the east front of the Allegheny Mountains Dr. Bassler obtained exhibition specimens illustrating faulting and its accompanying phenomena. In western Maryland a fault passes through a Silurian conglomerate composed of small, rounded pebbles of pure white quartz, forming an interesting educational object, and along the fault zone the conglomerate has been broken into angular

fragments and recemented together into a hard rock. In one case this recementation had been caused by silica and in another by iron ore. Large examples of both kinds of this fault breccia were collected. Photographs of these specimens in situ were secured so that explanatory exhibition labels can be illustrated.

THE COLLINS-GARNER FRENCH CONGO EXPEDITION.

In December, 1916, an expedition known as the "Collins-Garner Expedition in the interests of the Smithsonian Institution" sailed from New York for Bordeaux and from there to Africa, with the object of procuring a general collection of vertebrates and especially the great apes. The expedition encountered many difficulties and delays owing to the war, but by the summer of 1918 they had established permanent headquarters near Fernan Vaz, French Congo. A letter from Mr. R. L. Garner, who has the general management of the expedition, states in part:

Our domicile is located on the edge of a vast plain, traversed here and there by belts and spurs of forest. In those plots of bush live great numbers of chimpanzees, and for the first time in my long experience among them I have seen whole families of them out on the open plain. Frequently they cross the plain from one belt of bush to another, in some places a mile or so in width, and not a tree or bush in that distance to shelter them from attack. They often come within 200 to 300 yards of my house and sometimes manifest deep interest in trying to find out what this new thing is set up in their midst. I have seen as many as four or five different groups of them in the same day, and one of these contained 11 members.

Mr. Aschemeier has collected well on to 2,000 specimens, and nearly all of them he has killed with his own gun. Some of these specimens are exceedingly rare and valuable. When you recall the fact that he came as taxidermist of the expedition and not as chasseur, he was not expected to provide the specimens that he was to preserve.

We have forwarded six consignments of specimens to the Museum and have a seventh well on the way; but we find great difficulty in getting the steamers to take them from Port Gentil (Cap Lopez), because they are all under the direction of the French military authorities. Two of our last shipments were still at Port Gentil last month, where one of them has been lying since last January and all steamers declined to take it. Once both shipments were taken aboard the steamer and bill of lading signed when the captain changed his mind and sent the whole lot back on shore, with the accumulated charges of 40 francs for embarkation and debarkation.

We have sent 12 or 13 specimens of buffalo, several specimens and species of antelope, and two or three fine specimens of the "red river hog," beside a large collection of monkeys, representing six or seven species of both sexes and various ages. I think in all we have sent over 1,500 up to this time. Of course, this includes birds, etc., not insects, and we have on hand a goodly number.

War conditions seriously interfered with the shipment of the material collected, but later on a large number of interesting specimens were received by the Museum.

THE SMITHSONIAN AFRICAN EXPEDITION.

Shortly before the close of the fiscal year a collecting expedition to Africa was organized, to be known as the Smithsonian African Expedition, under the direction of Edmund Heller, in conjunction with the Universal Film Manufacturing Co. The expedition sailed from this country a few days after the close of the year for Cape Town, Africa, from which city arrangements were to be made for the plunge into the interior of the continent. The expedition is to collect animals, plants, and other material for uses of comparison in working up the collections made in Africa by Col. Theodore Roosevelt, Paul Rainey, and others, already in the National Museum. Representatives of the Universal Film Manufacturing Co. accompanied the expedition to make extensive motion pictures of life in the mysterious interior. The expedition will explore the jungles, deserts, lakes, and rivers and will be out at least a year.

Exploration is contemplated in various parts of the Cape region, the great Victoria Falls of the Zambesi River, and western Rhodesia. From there the expedition will cross to the sources of the Congo in Belgian Congo, then turn east toward Lake Tanganjika, following, to some extent, the trails of Livingston and Stanley in this region. From the town of Ujiji, on the eastern shore of the lake, the temporary headquarters of the expedition, excursions will be made into the former German East Africa and the Uganda Protectorate, especially the Ryvenzori Mountain region.

The primary purpose of the expedition is to secure additional specimens of plants and animals, chiefly from the interior and from South Africa, in which the Museum is rather deficient. These will prove a welcome supplement to the magnificent collections brought home by Col. Theodore Roosevelt and others and on which monographic reports are desired, but which can not be worked up intelligently and satisfactorily until more material is obtained. The experienced collectors, Mr. H. C. Raven, representing the institution, and Dr. H. L. Shantz, of the Department of Agriculture, will undoubtedly send back to this country much material of value concerning the little-known parts of the "Dark Continent" which have puzzled scientists and laymen for a long time.

BOTANICAL EXPLORATIONS IN ECUADOR.

As a part of a cooperative plan for an investigation of the flora of northern South America, organized by the United States National Museum, the New York Botanical Garden, and the Gray Herbarium, Dr. J. N. Rose, associate curator in the division of plants of the Museum, spent three months making botanical collections in Ecuador. A large quantity of desired material, including 6,000 botanical speci-

mens, 100 jars of fruit seeds and plant products preserved in formalin, a number of wood specimens, and samples of bark, was collected. It is expected that this and other proposed botanical researches in this region will be of much value to the agricultural and horticultural interests in this country.

In the course of Dr. Rose's work in Ecuador two sections were made of the coast across the western range of the Andes to the interior Andean Valley; one in the south from Santa Rosa to Loja, and the other near the center of the country from Guayaquil to Riobamba. A longitudinal section was made down the Andean Valley from San Antonio to Loja. This last section was over the route followed by Alexander von Humboldt at the beginning of the eighteenth century. Many of the plants collected by him on this memorable journey were re-collected.

CINCHONA BOTANICAL STATION.

With the consent of the governor of Jamaica the three-years' lease of the Cinchona Botanical Station, held by the institution, was canceled during the period of the war, as it was found impracticable to undertake any botanical research there during the unsettled conditions prevailing. The lease was terminated, however, with the hope that it could be taken up again with the return of normal conditions, and a few days after the close of the fiscal year a letter was received from Prof. Duncan S. Johnson, chairman of the committee of subscribers to the maintenance of the station, at that time in Jamaica, stating that he had begun negotiations with the Government to renew the lease, beginning January, 1920.

ANTHROPOLOGICAL WORK IN PERU AND BOLIVIA.

Mr. Philip A. Means, honorary collaborator in American archeology, United States National Museum, spent some months during the year in archeological work in Peru and Bolivia. The region around Lima, according to Mr. Means, is undoubtedly one of the richest in South America from the archeological standpoint. After visiting a number of the ancient ruins in this section, considerable time was spent in examining the archeological collections of several South American scientists. In an account of his work, Mr. Means says:

Two of the least known places visited were Maranga and Pando. They are very close together, and are about 6 miles northwest of Lima. In its prime, Maranga had four fine terraces, with a spacious terreplein at the top. At the bottom the pyramid is about 450 feet square and the summit terreplein is about 250 feet by 350. The material of construction is adobe. This pyramid is probably of Inca construction; it is much like the Inca-built Temple of the Sun at Pachacamac and has yielded many Inca artifacts.

Lying somewhat north and northwest of Maranga are the ruins of Pando. These cover an immense amount of ground, and consist of several pyramids

even larger than Maranga, but not so well preserved. The old city at this place was inclosed in a massive wall, with easily defended gateways. These latter were narrow, and, at either side, sunk in the thickness of the wall, there was a raised platform or niche where possibly a guard could stand and effectually oppose ingress.

At the western side of Pando there are the remains of a fine, though small, palace or temple. Although it is only about 85 feet square, this little building is remarkable on account of the attractive arabesque patterns made in the stucco coating of the walls. The western end of the main room was provided with a platform, raised some 3 feet above the rest of the floor. Behind this there was a passage which led to other apartments. It is not now possible to know exactly what sort of roof there was, for the wind has eroded the tops of the walls and signs of roof beams or joists are no longer visible.

THE PROPOSED ROOSEVELT MEMORIAL.

On January 29, 1919, a bill was introduced in the House of Representatives by Congressman F. C. Hicks, providing for the erection of a museum of history and of the arts as a memorial to Theodore Roosevelt. It was intended that the proposed museum would contain the extensive collections already in the National Museum of relics and mementoes of illustrious patriots of our country and of the events conspicuous in its history. The bill provides that the building should be planned and erected under the direction of the Regents of the Smithsonian Institution, and, when completed, would be administered by them. The site selected is the north side of the Mall, on a line with the present beautiful structure of the Natural History Building of the National Museum.

The memorial museum would contain also collections relating to arts and industries, including the great divisions of mechanical and mineral technology, such as objects and models illustrating the development of the electric telegraph and telephone; the phonograph; transportation by land, water, and air; musical instruments, from primitive to present forms; printing, illustrating, and bookmaking; photography, from the earliest invention to the modern moving-picture apparatus; ores and minerals, their natural occurrence, processes of extraction and manufacture, from the native state to the finished product; textiles; drugs; foods; and animal and vegetable products.

Provision would also be made for the present National Gallery of Art, in the development of which President Roosevelt took an active and timely interest. The collections of the National Gallery now approximate \$1,000,000 in value, and would grow more rapidly if adequate installation were insured.

In my letter to Congressman Hicks regarding the memorial, I stated, in part, as follows:

The proposed museum would not be a dead memorial, but a virile living tribute to Roosevelt that for ages would serve to educate and stimulate all classes of Americans. Its educational value would be great to the child, the

youth, and mature men and women. It would stimulate the historian, artist, designer, manufacturer, and artisan, and bring to the American people in the most realistic manner the extent and character of their historical and industrial development, and place side by side with the American many of the developments in art and science of other lands. I can not conceive of a more powerful influence for good that could take the form of a memorial to Roosevelt.

We have the great monument to Washington, the great mausoleum to Lincoln, and if on the same great parkway between the Capitol and the Potomac this tribute to Roosevelt could be erected it would be a tribute worthy of what he himself stood for in the life and thought of our country.

The bill providing for this memorial to Theodore Roosevelt was not brought up before the Congress for action during the session, at which it was introduced, but it was reintroduced on May 21, 1919, during the first session of the Sixty-sixth Congress, and at the close of the fiscal year was still in committee.

RESEARCH CORPORATION.

The Research Corporation, mentioned in several previous reports, is the outgrowth of the gift to the Smithsonian Institution by Dr. F. G. Cottrell of his patents covering the electrical precipitation of suspended particles.

The process is now in successful operation in a number of smelting and refining plants in which the precipitation of fumes is an important item. From the income of these applications there was established a fellowship, amounting to \$2,500 each year, for research along technical lines.

POPULAR SCIENTIFIC LECTURES.

In furthering one of the purposes of the Institution, "the diffusion of knowledge," a series of popular scientific lectures, illustrated by lantern slides, was instituted during the year, and given in the auditorium of the National History Building of the Museum. These lectures were open to the public and were all well attended, showing the interest of the people of Washington in scientific matters. Eight lectures were given in the series, on alternate Saturday afternoons, as follows:

1. Photographing in the Canadian Rockies, by Charles D. Walcott.
2. Sun Rays in Many Lands, by C. G. Abbot.
3. The Indian as a Stone Mason, by J. Walter Fewkes.
4. Meteorites and Shooting Stars, by George P. Merrill.
5. The Story of Our Local Aborigines, Historic and Prehistoric, With Demonstrations of Their Instrument Making, by William H. Holmes.
6. Harmful and Beneficial Insects, and How the National Museum Helps in Their Study, by L. O. Howard.
7. The Story of Silk, by Frederick L. Lewton.
8. Why the Wild Flowers Are So Wild, by Frederick V. Coville.

It is intended to continue these lectures during the coming year.

CONGRESS OF AMERICANISTS.

The twentieth international congress of Americanists which was to have been held at Rio de Janeiro in June, 1919, was postponed until the following year, when more favorable conditions may be expected.

PUBLICATIONS.

The institution and its branches issued during the year 98 volumes and separate pamphlets. The total distribution was 161,288 copies which includes 404 volumes and separate memoirs of Smithsonian Contributions to Knowledge, 15,603 volumes and separate pamphlets of Smithsonian Miscellaneous Collections, 13,885 volumes and separates of the Smithsonian Annual Reports, 118,332 volumes and separates of the National Museum publications, 11,483 publications of the Bureau of American Ethnology (all series), 1,444 special publications, 10 volumes of the Annals of the Astrophysical Observatory, 69 reports of the Harriman Alaska Expedition, and 58 reports of the American Historical Association.

An unusually large number of publications were in press at the close of the year, owing to the overcrowded condition of the Government Printing Office during the war.

Allotments for printing.—The allotments for the year for the printing of the Smithsonian report and the various publications of the branches of the Institution were practically used up and the allotments for the year ending June 30, 1920, are as follows:

For the Smithsonian Institution: For printing and binding the annual reports of the Board of Regents, with general appendices, the editions of which shall not exceed 10,000 copies.....	\$10, 000
For the annual reports of the National Museum, with general appendices, and for printing labels and blanks and for the bulletins and proceedings of the National Museum, the editions of which shall not exceed 4,000 copies, and binding in half morocco or material not more expensive, scientific books and pamphlets presented to or acquired by the National Museum Library.....	37, 500
For the annual reports and bulletins of the Bureau of American Ethnology and for miscellaneous printing and binding for the bureau....	21, 000
For miscellaneous printing and binding:	
International exchanges.....	200
International Catalogue of Scientific Literature.....	100
National Zoological Park.....	200
Astrophysical Observatory.....	200
For the annual report of the American Historical Association.....	7, 000

Committee on printing and publication.—All manuscripts offered for publication by the Institution or its branches are considered by the Smithsonian advisory committee on printing and publication.

Thirteen meetings were held during the year and 79 manuscripts were acted upon. The membership of the committee is as follows: Dr. Leonhard Stejneger, head curator of biology, National Museum, chairman; Mr. N. Hollister, superintendent of the National Zoological Park; Dr. George P. Merrill, head curator of geology, National Museum; Dr. J. Walter Fewkes, chief of the Bureau of American Ethnology; and Mr. A. Howard Clark, editor of the Institution and secretary of the committee until his death in December, 1918, when Mr. Webster P. True succeeded him as editor and secretary of the committee.

LIBRARY.

The library of the Smithsonian Institution is maintained for the purpose of assembling a collection of periodicals and publications of a scientific nature, as well as the journals and other publications of scientific institutions of the world, the whole forming a library of reference and research. In addition to the main bulk of titles housed in the Library of Congress, and known as the Smithsonian Deposit, there are 35 sectional technical libraries and 4 branch libraries—the National Museum library, the Bureau of American Ethnology library, the Astrophysical Observatory library, and the National Zoological Park library.

The number of accessions during the year which were added to the previous collection of over half a million titles numbered 7,502. Of these 2,077 were for the Smithsonian Deposit, 639 for the Smithsonian office, Astrophysical Observatory, and National Zoological Park, and 4,786 for the National Museum.

Seventy-eight titles have been added during the year to the institution's collection of aeronautical publications, in which continued interest has been shown by aeronautical research workers in the Army, Navy, and scientific institutions. Author cards for 1,722 titles of books in the De Peyster Collection have been made, and the 869 volumes on French history have been made accessible.

In the Museum library the most important acquisition was a set of catalogues of the J. Pierpont Morgan art collection, presented by J. Pierpont Morgan, jr. The technological library added 346 volumes, and the books in the sectional library, division of plants, have been revised and all available works on botanical subjects brought together and rendered accessible. The collection in the art room, statuary, as well as books, has been carefully gone over and put in thorough order.

NATIONAL MUSEUM.

The National Museum suffered the loss at the beginning of the year of the assistant secretary in charge, Mr. Richard Rathbun, who died July 16, 1918. His duties devolved upon Mr. W. de C.

Ravenel, the administrative assistant, whose title was changed to administrative assistant to the secretary, and on November 1 was also designated director of arts and industries.

The scope of the National Museum embraces many subjects, which may be classed under the following headings:

1. Natural history.
2. Applied science and art (Arts and Industries).
3. The fine arts (the National Gallery of Art).
4. American history.

These various departments are combined under one administration, which insures greater economy and efficiency in management.

During the war the Museum furnished the Bureau of War Risk Insurance with 138,600 square feet of space for its offices. Members of the Museum staff in all departments continued to render service to the various governmental agencies until the signing of the armistice, and their work was successful in bringing the Museum into closer relationship with the executive departments.

The total number of accessions received during the year was 526,845, classified and assigned as follows: Department of Anthropology, 12,333; Zoology, 442,383; Botany, 40,357; Geology and Mineralogy, 4,750; Paleontology, 26,050; Textiles, etc., 884; Mineral Technology, 62; and National Gallery of Art, 26. Three thousand and ninety-six articles were loaned for exhibition, mainly for the divisions of history and American archeology and the Gallery of Art. Purchases were made from the Frances Lea Chamberlain fund and the Henry Ward Ranger fund.

During the year the Museum began the collection of a most valuable and interesting series of war relics. One of the most instructive features of this collection is an exhibit showing the development of the airplane, from the original Langley models to the first Government-owned aeroplane of the world, purchased by the United States from the Wright Brothers in 1909. Through the director of military aeronautics, Bureau of Aircraft Production, two types of planes used by the French at the front in 1917 were received, and a Curtiss training plane of the model used at flying fields all over the United States, as well as the first battle plane constructed in this country for the United States Government—the DH-4—made by the Dayton-Wright Airplane Co. in 1917. This machine was flown over 100,000 miles.

The Department of Anthropology received exceptionally large additions relating to the war with Germany. They include the Combined Order of Battle Map, corrected to November 11, 1918, with its accessories, as used by Gen. Pershing and his staff at Chaumont, France, throughout the progress of the American military

movements; a collection of German military paraphernalia captured by American troops during various engagements; collections of the equipment of the various branches of the American Army; and an almost complete series of uniforms, insignia, decorations, and medals of the Army and Navy, as well as a collection of relics of Lieut. Benjamin Stuart Walcott, United States Army, who entered the French air service as a member of the Lafayette Flying Corps, and who was killed in aerial combat on December 12, 1917.

Another interesting addition consists of a large series of costumes and accessories worn by the late Richard Mansfield in his extensive repertoire of historic characters, presented by Mrs. Mansfield.

The chief addition in the Department of Biology was a collection of Antillean land mollusks, aggregating 400,000 specimens, donated by Mr. John B. Henderson, a regent of the Smithsonian Institution. The final installment of Dr. Abbott's Celebes collections was received likewise. The collections in the National Herbarium were enriched by a donation of 12,000 plants from Mexico, 9,600 from the Philippines, and many from the South American countries.

The Division of Textiles received for exhibition purposes from the office of the Surgeon General of the United States Army a collection consisting of apparatus, hospital appliances, and field equipment used by the Medical, Dental, and Sanitary Corps in the war. This included examples of all kinds of equipment of a thousand-bed hospital overseas. The food exhibits were continued and an arrangement was made with the States Relations Service of the Department of Agriculture, whereby regular demonstrations of the value, use, preparation, and conservation of foods were given. Over 2,100 persons attended the lectures and various demonstrations.

Work on the Freer Building progressed satisfactorily, and it is expected that the structure will be completed early in 1920. The National Gallery of Art acquired from Mr. Ralph Cross Johnson a rare gift of 24 paintings, which comprises selections from the work of 19 of Europe's foremost masters.

The most pressing needs of the Museum are a separate building for the National Gallery of Art, which has long since outgrown its present temporary quarters, and also one for American history. It is likewise imperative to increase the scientific and technical staff in order that the Institution may keep pace with the rapid development of the country.

The total distribution of Museum publications during the year aggregated 118,332 copies. Over 4,000 volumes, pamphlets, and unbound papers were added to the library, which now contains 54,685 volumes and 87,109 pamphlets and unbound papers.

BUREAU OF AMERICAN ETHNOLOGY.

The usual activities of the Bureau of American Ethnology, defined by law as "ethnological researches among the American Indians, including the excavation and preservation of archeologic remains," have been carried on during the year under the direction of Dr. J. Walter Fewkes, chief. Intensive studies were made of the dying languages of the numerous Indian tribes in order to discover the relationship of the various stocks of the aborigines and to gain a clearer insight into the origin, history, and migration of man on this continent. The continued study of the material culture of the Indians also has its practical value, while another instructive line of work relates to the history of the Indians both before and after the advent of Europeans.

Field researches include, in addition to those mentioned above, the excavation and preservation of archeological remains. A few of these researches are mentioned very briefly here in order to show the nature of the work. A somewhat more detailed account of these and other undertakings of the bureau during the year will be found in an appendix hereto. Valuable work was done by Dr. Fewkes in the McElmo and tributary canyons in Colorado and in Utah as far west as Montezuma Canyon, on the aboriginal castles and towers of that region, and through his efforts the Aztec Spring Ruin was presented by the owner, Mr. Henry van Kleeck, of Denver, to the National Park Service, and accepted by the Secretary of the Interior.

Dr. J. R. Swanton, ethnologist, devoted much of his time to the collection of material from published sources for a study of the economic background of the life of the American Indians north of Mexico. He has also continued his study of the languages of the Indians of the lower Mississippi Valley and of the social systems of the Choctaw and Chickasaw Indians.

Mr. J. N. B. Hewitt, ethnologist, prepared for the press the Onondaga version of the Myth of the Beginnings, the Genesis Myth of the Iroquoian peoples, and continued his previous study of the league.

Mr. Francis LaFlesche, ethnologist, is now completing for publication his notes on the rite of the chiefs, the tribal rite of the Osage people. In this ritual is embodied the story of the four stages of the development of the tribal government, including both the military and the civil forms, beginning with the chaotic state of the tribal existence.

Mr. J. P. Harrington, ethnologist, has obtained important corroborative evidence of the validity of his discovery that there is a close genetic relationship between Tanoan pueblo dialects of New Mexico

and the Kiowa. The bearings of this discovery on theories of the origin of modern Pueblos is very significant.

Special research work was done among the Salish Tribes, the Pawnee, and Chippewa. Dr. Walter Hough, curator of ethnology, United States National Museum, undertook archeological work in the White Mountain Apache Reserve, Arizona, and Mr. Neil M. Judd, curator of American archeology, United States National Museum, successfully investigated five prehistoric ruins in the Cottonwood Canyon caves. Dr. Aleš Hrdlička, curator of physical anthropology, United States National Museum, was detailed to make an examination of the remains of southwestern Florida, especially of the shell heaps along the coast south of Key Marco. Mr. Gerard Fowke has made careful detailed study of the numerous caves in the Ozark region of central Missouri, and also transmitted a valuable collection of relics to the Museum.

The number of publications distributed was 11,483, an increase of 4,139 over the number sent out last year. The library accessioned 380 new books and 210 pamphlets.

INTERNATIONAL EXCHANGES.

The total number of packages handled by the International Exchange Service during the year was 270,860, an increase over the number for the previous year of 3,914. Although it has not yet been possible to put the service on a prewar basis as far as the shipment of consignments abroad is concerned, shipments in boxes are being made as frequently as present conditions will permit to all countries except Austria, Bulgaria, Germany, Hungary, Montenegro, Roumania, Russia, Serbia, and Turkey.

The exchange service has continued its policy of international helpfulness in procuring publications desired by governmental and scientific establishments both abroad and at home. As an instance of this service, sets as nearly complete as possible of posters relating to the war were assembled and transmitted to the British Museum at their request, a similar service having been rendered to the French Government the previous year. Owing to the excessive charges on ocean freight, many packages were sent by mail.

Late in the fiscal year shipments to Belgium and the northern neutrals were resumed. The chief of the Belgian Service of International Exchanges said, in part, in a letter to the office here:

I should fail most lamentably in my duty, Mr. Secretary, if I did not add to this reply warm thanks in the name of the Belgian Government, in the name of our scientific establishments and institutions, and in my own name, for the extreme kindness you have shown us in reserving for us until the present time all the numerous "series" and "collections" (one and all of inestimable value) which the war has prevented you from transmitting to us at the proper time.

THE NATIONAL ZOOLOGICAL PARK.

The National Zoological Park continues in popularity as a means of natural history education and as a place of recreation and amusement for the people of Washington.

The total number of animals in the park at the close of the fiscal year was 1,336, including 528 mammals, 71 reptiles, and 737 birds. Among the more important additions were two young Sumatran elephants, purchased at a cost of \$5,000, for the children of Washington by a number of their friends and donated to the institution. At the time of their arrival they were about 2½ years old and were the first of their kind to be exhibited in Washington. Other important additions were a fine capybara, from the Hon. Henry D. Baker, Trinidad, British West Indies; a great white heron of southern Florida, from Dr. Paul Bartsch; and a pair of Florida bears from Mrs. A. V. N. Stroop.

Visitors to the park during the year numbered 1,964,715—a daily average of 5,383. Ninety-eight schools and classes visited the collection for instruction purposes.

Among the recent improvements are exterior cages for leopards, jaguars, and hyenas, and a new chimney for the central heating plant. A part of the creek-side drive was rebuilt, some animal houses were painted, and small improvements in the animal houses and yards were likewise effected.

The need of a new house for the exhibition of birds continues to become more urgent from year to year. An increased appropriation for the expenses of the park is also badly needed, as well as one sufficient for the purchase and transportation of animals, so that the park may take advantage from time to time of opportunities to obtain rare and conspicuous animals not before exhibited. The purchase of a frontage of over 600 feet on Connecticut Avenue, urged for several years by the superintendent, but which has not yet been considered favorably by Congress, would satisfy all the needs of the park as regards necessary expansion and better service to the public on the west side; and it becomes more and more important to secure this land, as the probability of losing the opportunity increases every year. It is also desirable to purchase a small strip of privately owned land between the park and the important highway of Adams Mill Road, because of improvements being made at that point by the District government. The incorporation of this land within the park is of very great interest to the public.

The slight increase in the annual appropriation granted by Congress scarcely more than covered the increased cost of maintenance of the park, even by practicing the strictest economy. Lack of funds for grading banks and filling ravines has prevented the com-

pletion of work begun three years ago for the purpose of obtaining new level spaces for yards and inclosures.

ASTROPHYSICAL OBSERVATORY.

Several important investigations relating to the war, begun last year, were continued by the staff of the Astrophysical Observatory under the general direction of Dr. C. G. Abbot, in addition to the regular work of the observatory. These researches are mentioned elsewhere in this report under the heading "General considerations."

At Washington work on solar radiation computations has gone on steadily, and progress has been made with the preparation of a new medium, potassium iodide, for the investigation of the rays beyond where rock salt is transmissible. A new instrument, based upon the principle of the perfect radiator, or "absolutely black body," was constructed for the purpose of measuring nocturnal radiation, such as the earth sends out to space. At the close of the year this instrument was reported as operating successfully on Mount Wilson.

In view of the fact that the total eclipse of the sun of May 29, 1919, would be visible at La Paz, Bolivia, which is not very far from the Smithsonian solar constant observing station at Calama, Chile, a successful expedition was undertaken by Dr. Abbot, with the double purpose of observing the eclipse and visiting the Calama station. Good photographs of the phenomenon and also pyranometric observations by Mr. A. F. Moore of the brightness of the sky were obtained during the progress of the eclipse. A conference was held with officials of the Argentine Government, which is likely to prove of great value in the future, in that it concerned the employment of solar-radiation measurements for weather forecasting by the Argentine meteorological service. At Calama, Chile, Dr. Abbot, in cooperation with the Smithsonian observers there, Messrs. Moore and Leonard Abbot, devised a new method of reducing solar radiation observations, so as to determine the solar constant of radiation with at least equal precision to that obtained by the older method, the advantages of the new method being (1) its independence of the variability of atmospheric transparency; (2) the time required is only one-fifth of the former period.

On Mount Wilson Mr. Aldrich continued the observations of the solar constant of radiation, and in September, 1918, made an interesting observation in cooperation with the Army Balloon School at Arcadia, Calif., on the measurement of the reflection of sun and sky radiation from layers of fog, which led him to conclude that a great horizontal fog bank reflects to space 78 per cent of the radiation of the sun falling upon it.

The preparation of Volume IV of the *Annals of the Astrophysical Observatory* has been in the hands of Dr. Abbot since February; it includes the results of measurements from the year 1913. Mr. Fowle has continued the work of revising the *Smithsonian Physical Tables*, in which he has received valuable aid from the various scientific departments of the Government and from individuals in colleges and industrial corporations.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

The United States Regional Bureau of the Catalogue, supported by congressional appropriation under the direction of the Smithsonian Institution, undertakes to list and index all scientific articles appearing in the United States each year. These titles are forwarded to the Central Bureau in London, where they are incorporated with the lists from all other countries in a comprehensive catalogue of the year's scientific work of the world. The war and the chaotic conditions in Europe since the war, have greatly hampered the work of the catalogue and it has been recognized for several years that a general reorganization will be necessary when conditions become more settled.

The Central Bureau has published during the year 8 volumes of the Thirteenth Annual Issue, completing that issue, and 12 of the 17 volumes of the Fourteenth Issue have appeared. The United States Bureau has continued to gather and index the scientific titles in this country, and in some of the sciences, notably zoology, the titles have been classified far in advance of the published volumes.

It has been recently announced by the Royal Society of London, the principal sponsor of the catalogue since its inception, that after the completion of the Fourteenth Annual Issue a new financial arrangement will be necessary in order to continue the work, and scientific establishments and academies throughout the world have been asked to offer suggestions as to the best method of accomplishing this end.

NECROLOGY.

I may here express for myself and on behalf of the staff of the Institution and the National Museum the deep sense of loss caused by the death during the year of Mr. Richard Rathbun, assistant secretary in charge of the National Museum, and Mr. A. Howard Clark, editor of the *Smithsonian Institution*. These two men, through long connection with the Institution, contributed much to its development and their passing leaves a deep feeling of personal loss among their associates.

RICHARD RATHBUN.

Richard Rathbun, assistant secretary of the Smithsonian Institution, was born in Buffalo, N. Y., January 25, 1852, and died July 16, 1918. He received his education at Cornell University, specializing in geology and paleontology. Here he was associated with Charles Fred Hartt, professor of geology, who assigned to Mr. Rathbun the task of working up for publication a collection of fossils from Brazil, which resulted in the publication of Mr. Rathbun's first paper on the "Devonian Brachiopoda of Erere, of the Province of Para, Brazil." During this work he had occasion to visit the Museum of Comparative Zoology at Cambridge, where the environment proved so congenial that he remained here for two years. During the summer months he served as a volunteer assistant under Spencer F. Baird in marine explorations on the New England coast. Through his association with Prof. Baird his connection with the Smithsonian Institution began.

In 1875 he was appointed geologist to the Geological Commission of Brazil, and for the following three years he studied the geological features of that country. On returning to the United States he was appointed a scientific assistant in the United States Fish Commission, in which service he remained until 1896.

During this period several papers from his pen appeared in "The Fisheries and the Fish Industry of the United States." During these years also he was involved in the fur seal investigation. The most important international commission to the Fur Seal Islands was the one sent out in 1896, and Mr. Rathbun was named chief advisor to Mr. Hamlin in immediate charge of the case.

In 1896 Mr. Rathbun came to the Smithsonian Institution and at the beginning of 1897 took up the duties as assistant in charge of office and exchanges, later being named assistant secretary. The following year, holding this same title, he was given charge of the National Museum, which position he held until his death.

One of the most important events during his administration of the Museum was the appropriation for and the construction of the new Natural History Building, in which he took a deep interest, and for which he was in large part responsible. He also undertook the development of the National Gallery of Art, a feature of the Smithsonian which is mentioned first in the act creating the Institution, but which had remained dormant for lack of adequate facilities.

Mr. Rathbun was a member of many scientific societies, including several foreign connections. His bibliography contains nearly 100 titles, including the numerous papers written during his connection with the Fish Commission, and his official reports as administrator of the National Museum.

ALONZO HOWARD CLARK.

Alonzo Howard Clark, editor of the Smithsonian Institution, was born in Boston April 13, 1850, and was educated at Wesleyan University, receiving an honorary degree of M. A. in 1906. Mr. Clark's first connection with the Government service was in 1879, when he was put in charge of the United States Fish Commission Station in Gloucester, Mass. In 1881 he was made curator of the division of history of the United States National Museum, and later editor of the Smithsonian Institution, which position he held until his death on December 31, 1918. Mr. Clark was also affiliated with a number of patriotic and historical societies, being secretary and registrar general of the Sons of the American Revolution, and an officer of the Society of Mayflower Descendants and of the Society of Colonial Wars. Matters of patriotic and historical interest were Mr. Clark's chief delight, and it was through his efforts that were begun the present great historical collections in the Museum. He was especially fitted for his position as curator of this division through his wide experience in historical and genealogical work and his many connections with organizations of that nature. Mr. Clark also held a prominent place in the activities of the American Historical Association, being secretary of this organization from 1889 to 1908, and curator from 1889 until the time of his death.

Respectfully submitted.

CHARLES D. WALCOTT, *Secretary.*

APPENDIX 1.

REPORT ON THE UNITED STATES NATIONAL MUSEUM.

SIR: It is with profound sorrow that I record the death at his home in this city on July 16, 1918, of Richard Rathbun, assistant secretary of the Smithsonian Institution since 1897, and, as such, in charge of the United States National Museum since 1898.

Out of respect to his memory the flags on the buildings of the Institution were carried at half-mast until after the interment of his remains in Rock Creek Cemetery on July 18. Business was suspended in the offices and the public exhibition halls were closed on the day of his funeral.

This is not the place to give an adequate review of the work of Mr. Rathbun as a man of science, or to recall his contributions to the upbuilding of the institution with which he was so long connected. I may be permitted, however, to express here my sense of bereavement in the passing of a man whose friendship and personal and official confidence I was permitted to enjoy.

During Mr. Rathbun's disability, and after his decease, the administration of the Museum devolved upon me as next in authority.

On November 1, 1918, the position of assistant secretary of the Smithsonian Institution in charge of the United States National Museum was discontinued, and I, as directed by you, assumed charge of the administrative affairs of the Museum, with the title of administrative assistant to the secretary. In addition to the general duties of the above assignment, I was designated director of arts and industries.

Introduction.—The scope of the National Museum embraces many subjects, which may be classed under the following headings:

1. Natural history, comprising zoology, botany, geology, mineralogy, paleontology, physical anthropology, ethnology, and archeology.
2. Applied science and art (Arts and Industries).
3. The fine arts (National Gallery of Art).
4. American history.

At the capitals of the principal countries abroad there are generally several separate Government museums for these various classes, notably in London and Paris, resulting from the independent origin of the different collections. In London, for example, the subjects combined in the United States National Museum are distributed be-

tween two sections of the British Museum (Bloomsbury and South Kensington), the Victoria and Albert Museum, the Science Museum, the Museum of Practical Geology, Bethnal Green Museum, the Wallace Collection, the several national galleries of art, and others. In Washington, on the contrary and very fortunately, the entire museum scheme has, by law, been essentially combined under one administration, which not only insures greater economy in management, but permits of a more logical classification and arrangement, the elimination of duplication, and a consequent reduction in the relative amount of space required.

The national collections of the United States are not yet to be compared as a whole with those of certain European countries, though in natural history they are probably not surpassed there. In respect to the fine arts, the Freer collection comprises the most important representation of oriental art in the world. However, in the fine arts generally and in the useful or industrial arts the National Museum has a great task before it, possible of accomplishment only when requisite facilities are supplied.

Steps were taken during the year looking to the more definite organization of the department of arts and industries. Elaborate classifications have been proposed from time to time, but none of these have been strictly followed in the arrangement of the collections, due mainly to the limitation of space. Work is being chiefly centered at present on those subdivisions which are most prominent in relation to current industrial affairs, but there are other subdivisions with important collections which are not represented by experts on the staff on account of lack of funds for their employment. As at present constituted the Department of Arts and Industries may be considered to consist of the Division of Mineral Technology, the Division of Textiles, the Section of Wood Technology, the Section of Foods, the Division of Medicine, and the Division of Mechanical Technology.

War activities.—In the last report the action of the Board of Regents of the Institution at the request of the President of the United States in closing the natural history building to the public on July 16, 1918, was noted, enabling the Museum to furnish the Bureau of War Risk Insurance of the Treasury Department with 138,600 square feet of space for office purposes on the ground and the two exhibition floors. This was done with the understanding that the Museum would be vacated upon the completion of the building then being erected for the bureau at the corner of Vermont Avenue and H Street, and that the Museum space would be turned back to the Museum authorities in the same condition in which it was received by the bureau. Late in March the bureau moved to its own structure, but its funds were then so depleted that it was unable to carry

out the agreement as to renovating the building. It was therefore unfortunately necessary to reopen the natural history building without making the needed repairs, the first floor being opened to visitors on April 11 and the second floor on April 22.

Advantage was taken of the closing of the exhibition halls to give additional attention to classifying, arranging, labeling, and otherwise putting in shape the study series in the various departments. In the department of geology this also afforded opportunity to thoroughly clean and to some extent rearrange the exhibition series, so that when reopened to visitors the halls were more interesting than ever.

From the beginning of the fiscal year until the signing of the armistice on November 11, members of the Museum staff in all departments continued along the same general lines as last year to render service to the various governmental agencies more directly engaged in prosecuting America's part in the great conflict. Much valuable assistance was thus given, and the cooperation of the Museum in this work has resulted in bringing it into even closer relationship with the executive departments with beneficial results.

War collections.—Early in the fiscal year, in cooperation with the War and Navy Departments, the Museum undertook the assembling and installation of a collection of materials relating to the late war, which will probably form one of the most important collections ever undertaken by it, and may, ultimately, need a separate building. It is proposed to perpetuate the part taken by the United States in the World War by preserving and exhibiting objects graphically illustrating the military, naval, and aerial activities, not only of our own side of the conflict but of our opponents as well.

The value of such a collection can not be overestimated from the popular or scientific standpoint, not only forming a fitting and serviceable supplement to the written and printed records relating to the history of the war, but constituting a most notable memorial to the patriotic forces represented by the individuals who have contributed to the preservation of civilization. It will be of the highest value for historical and scientific research.

The scope of this exhibit includes not only the general military equipment, such as tanks, field and machine guns, and other objects used by military organizations, naval equipment, including models of ships, naval guns, docks, yards, etc., airplanes, battle planes, but accessories of all kinds; individual military and naval equipment of the various branches of the service, such as clothing, arms, and other paraphernalia, military and naval decorations and medals, commemorative medals of notable events, mementos, trophies, pictures, paintings, photographs, maps, books, pamphlets, manuscripts, and other objects of the same character relating to the progress of the war.

As the natural history building was closed and every available foot of space in it assigned to the Treasury Department, it became necessary to install the material received during the year for the war collections in the arts and industries building, and to place the large and heavy objects in the open to the west of this building. At the close of the year material for the war collections was coming in steadily, and it had become necessary also to assign to this subject all of the central portion of the ground story and the rotunda of the natural history building—space usually reserved for special exhibitions.

The Museum is particularly fortunate in having a very excellent series of objects showing the development of the airplane, beginning with the Langley models, which have been in its possession for a number of years, and the first Government-owned aeroplane of the world purchased by the United States from Wright Brothers in 1909. Through the director of military aeronautics, Bureau of Aircraft Production, two types of planes used by the French at the front in 1917 were received during the past year, and a Curtiss training plane, such as used at all the training fields in the United States, and the first battle plane constructed in this country for the United States Government—the DH-4, made by the Dayton-Wright Airplane Co. in 1917. This plane has flown over 100,000 miles and been in the air over 1,000 hours.

Through arrangement with the Army and Navy the Museum is planning to exhibit examples of every plane, engine, radio apparatus, and other accessory in production in the United States at the time of the armistice, and has secured for this exhibit the temporary metal structure erected on the Smithsonian grounds in 1917 by the War Department for the use of the Air Service.

Immediate needs of the Museum.—As pointed out in the report of three years ago, the pressing needs of the Museum are those for additional space for the accommodation of collections and for increase in the scientific and technical staff. It is clearly manifest that these needs must be met if the institution, with its numerous departments, is to keep reasonable pace with the development of the country as a whole. The space congestion especially becomes more pronounced and embarrassing with each passing day.

The natural history collections and the laboratories connected therewith require for their reasonable accommodation and administration the entire natural history building, a structure erected especially for this particular purpose. To-day, however, large areas in the building are assigned—and that from necessity—to the rapidly growing collections of the National Gallery of Art, and in larger measure even to the great accumulations of historical material relating to the late war which are just now demanding adequate atten-

tion. The older building, designed to accommodate the nationally important department of arts and industries, although not adequate in space to serve this purpose, is from absolute necessity half filled with a great body of unrelated exhibits, representing history, anthropology, and art.

The National Gallery of Art, now for the first time taking an enviable place among the galleries of the country, is crowded into the natural history building without possibility of expansion, and many liberally inclined collectors of art works who seek a permanent home for their treasures, and who may be favorably disposed toward Washington, are necessarily met with the statement that additional collections, if acquired, must go into storage. These possible benefactors of the national collection are thus turned to other institutions or to the auction room. The Nation is thus deprived of the possibility of building up, even by gift and bequest, collections of art, such as are highly prized and fully provided for by civilized nations generally. The sooner a building devoted to the fine arts, including all departments, is provided the more quickly will the American people find themselves in the forefront in all that characterizes the highest level of civilization.

American history, one of the most essential and vital of the departments of museum activity, is not better provided for than art. There is no provision for it save in the present overcrowded buildings. A building of an order commensurate with a great national purpose is an absolute essential, and its erection should be provided for with the least possible delay.

COLLECTIONS.

The total number of specimens acquired during the year was approximately 526,845. Received in 1,198 separate accessions, they were classified and assigned as follows: Department of anthropology, 12,333; zoology, 442,383; botany, 40,357; geology and mineralogy, 4,750; paleontology, 26,050; textiles, woods, medicines, foods, and other miscellaneous animal and vegetable products, 884; mineral technology, 62; and National Gallery of Art, 26. As loans for exhibition, 3,096 articles were also obtained, mainly for the divisions of history and American archeology and the gallery of art.

Material to the extent of 539 lots was received for special examination and report.

During the year the Museum made its first purchases from the Frances Lea Chamberlain fund, adding to the Isaac Lea collection of gems and to the Isaac Lea collection of mollusks, respectively. Through the generosity of Mr. B. H. Swales, a member of the staff, a small fund which has been given the donor's name was established

during the year for the purchase of additions to the collection of birds.

The council of the National Academy of Design inaugurated purchases from the Henry Ward Ranger fund by acquiring a landscape by Bruce Crane entitled "December Uplands." Under the conditions prescribed by the will of Mr. Ranger this painting was assigned to the Syracuse Museum of Art and can be reclaimed by the National Gallery of Art at any time during the five-year period beginning 10 years after the artist's death.

Anthropology.—The additions to the historical collections during the past year have been exceptionally large and are especially interesting on account of the fact that so many of them relate to the recent war with Germany. They also include, however, many objects of note connected with the history of the United States prior to that momentous conflict. Of special note in connection with the collection received relating to the war are many mementos of persons and events, battle-field trophies, military and naval uniforms, insignia, and field equipment. These include the Combined Order of Battle Map corrected up to November 11, 1918, with its accessories, as used by Gen. Pershing and his staff at Chaumont, France, throughout the progress of the American military movements, showing locations of all United States divisions and exact location at the signing of the armistice, with the same information as to armies of the Allies and enemies, besides a large amount of other information; a most interesting collection of German military paraphernalia captured during the various engagements in which the American troops participated and assembled in France by Maj. Gen. H. L. Rogers, United States Army, while serving as chief quartermaster of the American Expeditionary Forces; two French military airplanes used on the western front and the first battle plane built in America; collections of infantry, artillery, cavalry, air service, and chemical warfare equipment of the type used during the war; a practically complete series of the uniforms, insignia, decorations, and medals of the Army and Navy; a notable collection of relics of Lieut. Benjamin Stuart Walcott, United States Army, who entered the French air service as a member of the Lafayette Flying Corps, was killed in aerial combat, and fell within the German lines December 12, 1917; also loan collections of uniforms worn by French officers. The war collections already received will be supplemented by others until the Museum possesses a complete representation of the vast amount of paraphernalia required in the prosecution of a modern war, including representative series of objects actually used during the recent conflict by the United States, the Allies, and the enemy countries.

The most notable collection not connected with the war received by the division of history during the past year consists of a very

large and interesting series of costumes and accessories worn by the late Richard Mansfield in his extensive repertoire of historic characters, presented by Mrs. Mansfield. Many other historical relics were received, among them the gold medal awarded by act of Congress to Capt. Thomas Truxtun, United States Navy, in recognition of the defeat of the French ship *Vengeance*, February 1, 1800, lent by Mr. Thomas Truxtun Houston; a silver-mounted telescope owned by Thomas Jefferson, lent by Brig. Gen. Jefferson Randolph Kean, Medical Corps, United States Army; and a jeweled sword presented to Maj. Gen. John R. Brooke, United States Army, by American and Cuban friends in 1899.

The operations of the curators of the divisions of ethnology and archeology in Arizona have added considerably to the collections in archeology, and Dr. W. L. Abbott has supplemented the material generously contributed by him in previous years from Celebes with a large series of costumes, ornaments, and implements collected by Mr. H. C. Raven. Especially interesting are the decorative designs on the bark cloth used for costumes on these islands.

In physical anthropology very important accessions from the ancient pueblo region were received through Mr. F. W. Hodge, as a gift from the Museum of the American Indian, and as a gift from Dr. Edwin Kirk valuable crania and other physical remains from the territory occupied by the Haida and Tlingit tribes of Alaska.

Biology.—The number of specimens received during the year by the department of biology, totaling about 482,740, vastly exceeded the number accessioned last year. This great increase was chiefly due to the incorporation of the unrivaled collection of Antillean land mollusks, aggregating approximately 400,000 specimens, which was donated by Mr. John B. Henderson, a regent of the Smithsonian Institution. It is one of the most complete and extensive collections of its kind in existence not only because it contains nearly all the known West Indian species but because of the large number of types and authentic specimens which it includes. Among the many other important collections received, it may be well to mention the final installment of Mr. Raven's Celebes collections, which we owe to Dr. W. L. Abbott's generosity, and the interesting material from the Collins-Garner Expedition to the French Congo, containing as it does, besides a large number of birds and smaller mammals, three gorillas and several chimpanzees. Secretary Walcott, during his explorations in British Columbia, collected several large mammals for the Museum, including a mule deer, Rocky Mountain goat, and Rocky Mountain sheep, which made a valuable addition to our collections.

Among the additions to the National Herbarium may be particularly mentioned about 12,000 plants, chiefly from Mexico, donated by Brother G. Arsène and representing the result of eight years' botani-

cal collecting by himself and associates among the Christian Brothers. The collection of Philippine plants was greatly increased by the addition of two lots, aggregating more than 9,600 specimens, one received in exchange from the Bureau of Science, Manila, the other acquired by purchase. The South American series was also augmented considerably by the donation of 1,761 Venezuelan plants by Dr. H. Pittier and 1,077 specimens exchanged with the Museu Goeldi in Para, Brazil, besides the Museum's share of about 2,000 specimens from the Ecuadorean Andes collected by Dr. J. N. Rose on an expedition undertaken jointly with the New York Botanical Garden and the Gray Herbarium; while exchanges with the last-mentioned institution added approximately 1,450 more South American plants.

The exhibition collections were closed most of the year on account of the space having been turned over to the Bureau of War Risk Insurance. However, toward the end of the year the halls on the first floor, containing mostly the mammals and birds, including the great biological groups, were reoccupied by the Museum and opened to the public, after certain additions and improvements in the installation had been made.

Geology.—The additions to the collections in this department during the year were but 135 lots, aggregating an approximate total of nearly 31,000 specimens. This number, although somewhat less than that of the preceding year, is, in part, compensated for by the unusual value of sundry individual specimens. Among these may be mentioned examples of tungsten minerals both from domestic and foreign sources, including a magnificent specimen of scheelite presented by Dr. J. Morgan Clements, of New York City, and upward of 16.5 kilograms of the extraordinary meteorite which fell at Cumberland Falls, in Whitley County, Ky., on the 9th of April, 1919.

The availability of the Frances Lea Chamberlain fund has enabled the department to begin once more a systematic building up of the Isaac Lea gem collection. A 7-gram kunzite, a 16-gram black opal from Nevada, and 5 beautiful examples of Australian opals of a variety heretofore unrepresented in the collections are among the more important additions.

The Middle Cambrian collections obtained by Secretary Walcott from Burgess Pass in British Columbia number nearly 7,000 individual specimens, and form an addition of unusual value. The same is true of a collection including both fossil invertebrates and plants, mainly from Carboniferous and Silurian rocks of Indiana, and especially rich in beautifully preserved crinoids. This collection, comprising not less than 10,000 specimens, was a gift of Mr. Alva Schaefer, of Brazil, Ind.

Excellent exhibition materials in the line of vertebrate fossils, including part of a skeleton with a skull of the curious amphibial *Diplocaulus copei* from the Permian of Texas; a skull of *Monoclonius*; a skull, partial skeleton, and two hind paddles of *Tylosaurus*; and an articulated series of caudal vertebrae of *Platycephalus* are among the more important accessions. Mention should be made of the addition to the exhibition series of the mounted skeleton of *Dimetrodon gigas*, which was secured some few years ago. This forms the most complete restoration of this extraordinary animal that has thus far been secured by any museum in the world.

Museum work, as in other departments, suffered through interruptions, including the closing of the exhibition halls, incidental to the war, the head curator himself being engaged a part of the time in procuring for the National Research Council important materials needed in newly devised apparatus. Continual demands were made upon the department throughout the entire period of the war for materials for experimental purposes, and it is felt that the department fully justified itself in its capacity for supplying that which was needed.

Advantage was taken of the relief from all exhibition work caused by the closing of the halls, to complete the records and attend to other work such as had heretofore suffered more or less neglect through pressure of other duties.

Incidental mention may be made of the preparation of 100 lots in sets comprising 21 specimens each, illustrating the secular decay of rocks and intended primarily for distribution to the agricultural schools. Considerable progress was also made in the preparation of 100 sets of upward of 80 specimens each of ores and minerals which are intended for distribution as occasion may demand. This is a work which is ordinarily done at odd moments, as no funds are directly available for the purpose.

Textiles.—To the collections under the charge of the curator of textiles, which, besides textiles, embrace wood technology, medicine, food, and animal and vegetable products, the most important addition was the collection received by transfer from the Office of the Surgeon General of the War Department, consisting of apparatus, hospital appliances, and field equipment used by the medical, dental, and sanitary corps in the war with Germany, including examples of all kinds of equipment of a thousand-bed hospital overseas. At the end of the year this was being made ready for the public in connection with the war collections on the ground floor of the natural history building.

Among the gifts were medicinal plants, pharmaceutical products, pile fabrics, novelty dress fabrics, leather cloth, and other waterproof textiles extensively used during the war, knitting and crocheting

yarns with examples of pattern stitches, an extensive collection illustrating the production, classification, and conservation of foods, with many such from the Department of Agriculture and the United States Food Administration, and an exhibit illustrative of neglected sources of supply of fats and oils for food purposes.

In making the food exhibits as useful as possible a cooperative arrangement was entered into with the States Relations Service of the Department of Agriculture whereby regular demonstrations on the value, use, preparation, and conservation of foods were given at the Museum by experts of the department. A large room in the arts and industries building was fitted up as a demonstration kitchen and space provided for displaying foods, models, and household equipment. This work soon broadened into a household consultation center, with lectures and demonstrations covering a wide range of subjects. There were lectures on the Business of the household; Food for the family on \$2 per day; Direct marketing; What becomes of the consumer's dollar; What to give your children to eat; Milk, its nutrition and use; Meat substitutes; Housekeeper's use of market schedules; and Influence of weave structure upon the durability of fabrics. The demonstrations included labor-saving appliances for the kitchen; the fireless cooker; the pressure cooker; the electric washing machine; preserving eggs; cooking dinner in 30 minutes; the one-dish meal; invalid cookery; dried milk powder; Christmas sweets; sugarless candies; and fruit juices in summer drinks. By classes and demonstrations for housekeepers in the mornings and afternoons and special classes for war workers at 5 p. m., over 2,100 persons were reached during the year.

Mineral technology.—In mineral technology the customary work of the division was shelved in favor of special activities with a more direct bearing on the national emergency. As the war progressed the call for specialization on the part of its technical staff increased. While the country was still actively involved on a basis of war, scarcely a day passed without bringing calls from some governmental agency for assistance with reference to one or another industrial issue up for consideration on an emergency rating, the questions ranging from determining a fair price for mica to determining the likelihood of a paralyzing petroleum shortage. As the year advanced, however, two absorbing lines of special investigation developed to such a degree that during the latter half of the year they largely engrossed the attention of the staff. Their general nature may be gathered from the titles under which the results were issued. One, "A Report on the Political and Commercial Control of the Nitrogen Resources of the World," represents an effort to unravel the complexities of the nitrogen situation left behind in the passing

of the war. The other, "The Energy Resources, a Field for Reconstruction," coordinates and summarizes the work of several years.

THE NATIONAL GALLERY OF ART.

The National Gallery of Art is fortunate in the acquirement of art works of exceptional importance during the year. Among these the most noteworthy is a gift by Mr. Ralph Cross Johnson of 24 paintings, which comprises selections from the brushes of 19 of Europe's foremost masters. The Gallery is thus more fully assured of a worthy position among the galleries of the Nation. The extension of the Gallery's activities to wider fields than heretofore is marked by the acquirement by gift of an installment of a rich collection of art works of European origin from Rev. A. D. Pell, of New York.

Notwithstanding the prevailing labor conditions much progress was made during the year on the building being erected by the Institution at the expense of Mr. Charles L. Freer, on the southwestern corner of the Smithsonian reservation, to house the Freer collections of American and oriental art. The building was entirely inclosed at the end of the year, the exterior granite and marble walls and the roofs being completed. Work on the interior is now progressing satisfactorily, and it is expected that the structure will be entirely finished this autumn.

MEETINGS.

Shortly after the armistice was declared and as soon as the auditorium, which had been vacated late in November, could be repainted and the chairs replaced, there was inaugurated a series of popular lectures, under the auspices of the Institution, on alternate Saturday afternoons, between the hours of 4.45 and 5.30, commencing January 18, 1919. The lecturers and subjects are noted in the report of the secretary.

The meeting facilities afforded by the auditorium and committee rooms were also availed of, as follows:

By the United States Employment Bureau of the Department of Labor, for lectures by Dr. Meeker on the gathering and interpretation of statistics, and by Dr. Prosser on training of the handicapped; by the Children's Bureau for a conference on child's welfare, with an illustrated lecture; by the Ordnance Bureau of the War Department for an illustrated lecture by Lieut. Col. G. M. Barnes on battle scenes in the World War; by the Artillery Division of the Army for an illustrated lecture on the method in camouflaging used by that division during the war; by the Public Health Service of the Treasury Department for a moving picture, "Fit to win," before the

faculties and students of the departments of medicine and dentistry of the Georgetown University, with remarks by Asst. Surg. Gen. Pierce and by Dr. George E. Kober and Dr. Bruce L. Taylor; by various divisions of the Bureau of War Risk Insurance on numerous occasions for various purposes; by the American Society of Mammalogists; by the Wild Flower Preservation Society; by the Biological Society of Washington; by the Louisiana Society of Washington, with an illustrated lecture by Hon. M. F. Alexander, State commissioner of conservation, on the work accomplished by the Alabama Conservation Commission during the past 10 years; by the National Women's Trade Union League for a lecture by Miss Margaret Bondfield, of England, on the new spirit of British labor; by the Minimum Wage Board of the District of Columbia for a conference; by the District of Columbia Chapter of the Sigma Xi for its annual meeting and an illustrated lecture by Maj. R. M. Yerkes on the relationship of Army tests to education and vocational guidance; and by the scientific and technical Federal employees for the purpose of forming an organization with a view to joining the Federal Employees Union.

The main hall, range, and chapel of the Smithsonian building proving inadequate for the annual meeting of the National Academy of Sciences in April, the sessions of the last two days were transferred to the Museum auditorium. The auditorium was also used two days for a conference on the American merchant marine, the Hon. Joseph E. Ransdell presiding.

MISCELLANEOUS.

The distribution of duplicates for educational purposes, chiefly to schools and colleges, aggregated 3,441 specimens, while over 5,000 more were used in procuring additions to the collections through exchanges. Material sent for study to collaborators of the Museum and other specialists amounted to 19,851 specimens, mainly zoological.

During the approximate three months that the natural history building was open the attendance of visitors was 94,240 for week days and 38,619 for Sundays, an average of 1,149 for week days and 2,758 for Sundays. From November 10 to April 6 the opening of the arts and industries building was extended to include Sundays as well as week days, the attendance there for the year being 225,927 on week days and 40,605 on Sundays, a daily average of 721 for the former and 1,845 for the latter. At the Smithsonian building the total attendance was 101,504, with a daily average of 324 persons.

The publications of the year consisted of two annual reports, those for 1917 and 1918, two volumes of proceedings, four bulletins, and 71 separate papers. The total distribution of Museum publications during the year aggregated 118,332 copies.

The Museum library was increased by 2,172 volumes and 2,614 pamphlets and unbound papers, mainly procured by gift or exchange. Among the more important acquisitions was a set of catalogues of the art collections of J. Pierpont Morgan, presented by J. Pierpont Morgan, jr., the valuable library of Dr. Richard Rathbun, relating to the museums of the world and to natural history subjects, the gift of his heirs, and the 12 volumes of its Humanistic Series, donated by the University of Michigan. The library now contains 54,685 volumes and 87,109 pamphlets and unbound papers.

Respectfully submitted.

W. DE C. RAVENEL,
Administrative Assistant to the Secretary
in charge U. S. National Museum.

Dr. CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

AUGUST 25, 1919.

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APPENDIX 2.

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY.

SIR: In response to your request I have the honor to submit the following report on the researches and other operations of the Bureau of American Ethnology during the fiscal year ended June 30, 1919, conducted in accordance with the act of Congress approved July 1, 1918, making provision for sundry civil expenses of the Government, and following a plan submitted by the chief and approved by you as Secretary of the Smithsonian Institution. The act referred to contains the following item:

American ethnology: For continuing ethnological researches among the American Indians and the natives of Hawaii, including the excavation and preservation of archæologic remains, under the direction of the Smithsonian Institution, including necessary employees and the purchase of necessary books and periodicals, \$42,000.

The ethnological and archeological researches of the staff which are considered in the following report being by law restricted to the American Indians thus from necessity are more or less limited in scope, but notwithstanding this limitation and the intensive work that has been done in the past there is no indication that this field has been sufficiently cultivated or is approaching exhaustion. It is evident that aboriginal manners and customs are rapidly disappearing, but notwithstanding that disappearance much remains unknown, and there has come a more urgent necessity to preserve for posterity by adequate record the many survivals before they disappear forever.

The remnants of languages once spoken by large populations have dwindled to survivals spoken by one or more centenarians, and when they die these tongues, if not recorded, will be lost forever. Such a fate nearly happened with an Indian language in California last year on account of a contagious disease, but fortunately, through the field work of one of our staff, it was rescued before its extinction.

The continued study of the material culture of the Indians has a practical economic value. Certain food plants, like maize, and fibers, like henequen, have already been adopted from our aborigines, and there are others of vast economic value which await investigation. Ethnological studies of our Indians along these lines are being made by the members of the staff.

Another instructive line of work the past year relates to the history of the Indians both before and after the advent of the Europeans.

Such studies tend to a broader appreciation of racial character and have special value when we reflect how rapidly the Indian population is merging into American life. The excavation and repair of prehistoric monuments in our Southwest is enlarging our knowledge of history as well as attracting more and more tourists and replacing threadbare prejudices with saner ideas of Indian possibilities in many lines.

The logical results of the events of the last years appear in the calls for information made on the staff for accurate knowledge of other races besides the American Indian. It needs no prophet to predict that the future will demand an extension of the bureau work to other races. The calls for ethnological information on the Indian during the past year have been many and varied and considerable time of the ethnologists has been taken up in answering the many requests of this nature that are made. The chief has given much time to administration and routine work.

In addition to administrative duties the chief has been able to devote considerable time to research work in the field and has prepared for publication several scientific articles, the largest of which will soon be published as Bulletin No. 70. These field researches are in accordance with the above-mentioned act of Congress, which includes the excavation and preservation of archeological remains. In September he took the field, continuing his explorations of the castles and towers of the McElmo and tributary canyons in southwestern Colorado, extending his studies westward into southeastern Utah as far as Montezuma Canyon. The object was to determine the western horizon of the area of the pure type of pueblos and cliff dwellings, and to investigate the remains of antecedent peoples from which it sprung in order to obtain data bearing on the question of the origin of the San Juan drainage culture. The country traveled through is especially rich in prehistoric towers and castellated buildings, but contains also many clusters of mounds formed by fallen walls of large communal buildings, many of which were wholly or partially unknown to science. The work was largely a reconnoissance and no extensive excavations or repair work was attempted. Special attention was paid to the structure and probable use of towers which are combined with cliff houses like Cliff Palace, or great villages like those of the Mummy Lake and upper San Juan and its tributaries. Among the most significant new towers discovered were two found in McLean Basin, near the old Bluff City trail not far from the State line of Utah and Colorado. The McLean Basin ruin has a rectangular shape, with a round tower on one corner and one of semi-circular form on the diagonally opposite angle, each 15 feet high. The building on which these towers stand must have presented a very exceptional appearance in prehistoric times before its walls

had fallen. Another ruin found in a cave in Sand Canyon is instructive on account of its being the only one yet found with a single kiva of the unit type. It was probably a ceremonial cave, the room showing scanty evidence of having been inhabited.

One of the discoveries made was the recognition that the buildings on McElmo Bluff had a crude masonry characterized by stones set on edge, the walls being made of adobe and logs. The stones of one or more rooms on this site were large, indicating megalithic stone houses. All the data assembled indicate that they antedated the fine horizontal masonry of the pueblos and cliff dwellings.

While in the field the chief carried on a correspondence with Mr. Van Kleeck, of Denver, owner of the Aztec Spring Ruin, which led to that ruin being presented to the National Park Service and later accepted by the Secretary of the Interior. The presentation of this interesting ruin to the Government is important and it is to be hoped that it will later be excavated and repaired and thus present an additional attraction to tourists and an important aid to the archeologist in the interpretation of this type of southwestern ruin.

In May the chief visited Austin, Tex., and inaugurated work on the antiquities of that State, the archeology of which has been neglected. This work is now being prosecuted by Prof. J. E. Pearce, of the University of Texas, and bids fair to open up a most instructive chapter in a field of which we know comparatively little. Important discoveries have been made in the aboriginal workshops and village sites at Round Rock and near Austin, where fine flint implements are very abundant. The work will be continued into the timbered region of eastern Texas, where we find pottery related to that of Louisiana and Arkansas and evidences of a radically different prehistoric culture from that of central Texas.

Mr. James Mooney, ethnologist, at the beginning of the fiscal year was at his former field of labor among the Kiowa and associated tribes of western Oklahoma, where several months were devoted to the collection and revision of material and observations of ceremonies among the Kiowa, Comanche, Kiowa Apache, Cheyenne, Arapaho, Caddo, and Wichita in continuation of studies of their aboriginal heraldry, social and military organization, and religion.

Since his return to Washington in November he has been employed chiefly in the coordination of material obtained in the field and in the compiling of data for reply to current letters of ethnologic inquiry.

Dr. John R. Swanton, ethnologist, devoted a considerable part of his time during the past year to the collection of material from published sources for a study of the economic background of the life of the American Indians north of Mexico. This involves an exami-

nation of the sources, location, and quantity of food supplies and of new materials used in the industrial life of the various tribes—materials of wood, stone, bone, shell, etc. In this way it is hoped that a more complete understanding of the density and distribution of the prehistoric population may be reached, and the location and significance of trade routes established. A clearer idea is also sought of the shifts in population undoubtedly brought about by the introduction of corn. Without some study of the kind no proper estimate of the social and religious institutions of the people of prehistoric America is possible.

His work on the languages of the Indians of the lower Mississippi Valley has been continued, and at the end of the year it was directed particularly to the preparation of a grammatical sketch of the Natchez language from materials collected by him during the last 10 years from one of the three surviving speakers of that tongue.

In April Dr. Swanton visited Oklahoma in order to collect additional information regarding the little understood and now almost forgotten social systems of the Choctaw and Chickasaw Indians. Although small in bulk, the material obtained in the course of the investigation is valuable. It has already been incorporated into a manuscript paper on the social organization and social customs of the Indians of the Muskogean stock. During the trip he also secured the services of an educated Chickasaw in writing texts in his native tongue, and one of these has already been received.

Before his return to Washington, Dr. Swanton visited Anadarko, where he learned that the language of the Kichai Indians is on the point of extinction, and began the collection of a vocabulary. He has made arrangements for more extended work upon this language in the fall.

He has submitted two papers for publication during the year, first a philological paper entitled "A Structural and Lexical Comparison of the Tunica, Chitimacha, and Atakapa Languages," which is being published as Bulletin 68, in which he believes he has shown the relationship of what had hitherto been classed as three independent stocks; and, second, an extended historical study of the Creek Indians and their neighbors.

Mr. J. N. B. Hewitt, ethnologist, on his return from field work, July 5, 1918, took up the final reading of the proofs of his report in the Thirty-second Annual Report of the Bureau of American Ethnology. These proofs were sent to the Printing Office November 9, 1918, and the printed report was ready for distribution May 12, 1919.

At this time he also took up the work of preparing for the press the texts, with free and interlinear translations, of an Onondaga version of the Myth of the Beginnings, the Genesis Myth of the Iroquoian peoples, as the second part of Iroquoian Cosmology, the

first part having been printed in the Twenty-first Annual Report of the bureau. The copying of the pencil text was completed, aggregating 316 typewritten pages. This includes the supplementary myth of much later date than the accompanying version of the Myth of the Beginnings. The most interesting feature of the supplementary myth is the naive description of one of the most remarkable figures developed by the cosmic thinking of Iroquoian poets. This potent figure, in whose keeping are life and the endless interchange of the seasons, is most striking in his external aspect—one side of his body being composed of living flesh and the other of crystal ice. In the longer preceding myth, to which this is supplemental, the Master of Life is an independent personage, and so also is his noted brother, the Master of Winter, the Winter God, whose body is composed of crystal ice. The Life God, or Master of Life, controlled the summer, and his brother, the Winter God, controlled the winter. So in this peculiar figure there appears the inceptive fusing together of two hitherto independent gods who were brothers because they dwelt together in space and time.

This remarkable figure is, in fact, the symbol of the absorption of the personality—the functions and activities—of the Master of Winter (the Winter God) by the Master of Life and his powerful aids, manifested in the power of the Master of Life (the Life God) to save and to protect from dissolution and death his many wards, all living things that comprise faunal and floral life. This fact emerges from the experience of the human race from year to year. This submergence of one divine personality in that of another is a process of cosmic thinking encountered in the mythic philosophy of other races. This figure, as described in this text, is worthy of intensive study by the student of comparative mythology and religion. The pencil texts of these myths aggregate 1,057 pages and the typewritten 316 pages. The tentative draft of the free translations of these texts aggregates 250 pages of typewriting. Some work was also done in supplying the first text with a literal interlinear translation. This will be ready for the press at an early date.

Mr. Hewitt also continued work on his league material, in which he completed the copying of the corrected and amended native text of the tradition of the founding of the Iroquois League, or Confederation by Deganawida, making 189 typewritten pages, and also the amended and corrected text of the Chant of the Condoling and Installation Council, detailing some of the fundamental laws of the league; this occupies 13 pages.

Upon request, Mr. Hewitt also submitted an article on the League of the Iroquois and Its Constitution for the Annual Report of the Smithsonian Institution; it occupies 30 typewritten pages.

Mr. Hewitt has also attended the meetings of the United States Geographic Board, on which he represents the Smithsonian Institution.

As custodian of manuscripts, Mr. Hewitt has charged out and received back such items as were required by collaborators.

Mr. Hewitt also spent much time and study in the preparation of matter for official replies to letters of correspondents of the bureau or to those which have been referred to the bureau from other departments of the Government.

On May 12, 1919, Mr. Hewitt left Washington on field duty. His first stop was on the Onondaga reservation, situated about 8 miles south of Syracuse, N. Y. There he was able to record in native text all of the doctrines of the great Seneca religious reformer, Skanyo-daiyo ("Handsome Lake"). This is an important text, as it will serve to show just how much was original native belief and how much was added by the reformer from his impressions formed from observing the results of European intrusion. This text contains about 14,000 native terms. He also recorded the several remnant league rituals and chants which are still available on this reservation. But they are so much abbreviated and their several parts so confused and intermixed one with another that with these remains alone it would be absolutely impossible to obtain even an approximate view of their original forms and settings—a most disappointing situation for the recorder. Only the most elementary and superficial knowledge of the structure and constitution of the Iroquois League survives here.

Having completed his projected work at this reservation, Mr. Hewitt went, May 31, to the Six Nations reservation on Grand River, Ontario, Canada. Here he resumed the analysis, correction, amendment, and translation of the league texts which he had recorded in previous years. Satisfactory progress was made in this work up to the time of the close of his field assignment.

During the year Mr. Francis LaFlesche, ethnologist, devoted a part of his time to the task of assembling his notes taken at the time of his visit among the Osage people in the month of May, 1918. These notes relate to the tribal rite entitled Ga-hi'-ge O-k'o', The Rite of the Chiefs. The ritual contains 27 wi'-gi-es (recited parts), 20 of which belong to individual gentes and 7 of which are tribal.

In this ritual is embodied the story of the four stages of the development of the tribal government, including both the military and the civil forms, beginning with the chaotic state of the tribal existence.

The securing of the information relating to this rite required considerable tact, patience, and time, because the men familiar with all the details still regard the ancient rites with reverence and supersti-

tious awe. The transcribing of the wi'-gi-es from the dictaphone records and the translation of the words from the Osage into the English language were laborious and tedious tasks. This rite will soon be entirely forgotten, as it has been abandoned now for a number of years, and the rescuing of it for preservation has been timely.

This rite, which will make the first part of the volume now being completed for publication, covers 182 typewritten pages without the illustrations, maps, and diagrams.

The office of hereditary chief has been abandoned and since 1881 has been elective.

Upon the completion of *The Rite of the Chiefs*, the work of arranging for publication the ritual entitled Ni'-ki Wa-tho^a, *Song of the Sayings of the Ancient Men*, was taken up. This ritual tells of the origin of the people of the Ho^a-ga subdivision of the Ho^a-ga great tribal dual division. The story of their descent from the sky to the earth and of their subsequent movements is put into wi'-gi-e form and recited at the initiatory ceremonies. Each gens has its own version of the story and has in it a proprietary right, a right that in olden times was not infringed upon by the others.

Mr. LaFlesche was fortunate in becoming acquainted with an Osage by the name of Xu-tha'-wa-to^a-i^a and of winning his friendship. This man belonged to the Tsi'-zhu Wa-no^a gens of the Tsi'-zhu great tribal dual division. Without the slightest hesitation he recited for Mr. LaFlesche the Ni'-ki Wi'-gi-e of his own gens, and he also gave with it some of the shorter wi'-gi-es that accompany certain ceremonial acts of the ritual.

These origin rituals when completed will cover more than 220 typewritten pages, to which two short wi'-gi-es of a like character, nearly ready, will be added. These pages added to those of *The Rite of the Chiefs* will bring the number of typewritten pages, without the illustrations, close to 430.

The *Fasting Ritual*, which was completed some time ago, and covers 492 pages, exclusive of the illustrations, and the two rituals above referred to, will make the first volume of a projected work on the Osage tribe.

On July 1, Dr. Truman Michelson, ethnologist, visited Tama, Iowa, and completed his field work on the grammatical analysis of the text of "*The Owl Sacred Pack of the Fox Indians*." On his return to Washington he worked out a practically exhaustive list of verbal stems and submitted a manuscript for publication. He also observed mortuary customs under peculiarly fortunate conditions and obtained a number of texts written in the current syllabary on mortuary customs, eschatology, etc. He restored phonetically and translated, with a few exceptions, 310 personal names. He verified a previous discovery that certain gentes have their own peculiar names

for dogs and horses, and translated 127 of these names for a forthcoming paper on Fox sociology. Dr. Michelson finished the correction of Jones' Ojibwa Texts, part 2, which with part 1, previously corrected by him, will form the basis of a proposed sketch of Ojibwa grammar. During the fiscal year he also from time to time furnished data to answer official correspondence.

The beginning of the fiscal year found Mr. J. P. Harrington, ethnologist, at Taos, N. Mex., engaged in the correction and completion of his manuscript on the Tiwa language. The Taos material of the late Mrs. M. C. Stevenson, which is of considerable bulk and great value, was also checked up and made more complete, especially in its linguistic aspects. The close genetic relationship of the Tanoan dialects of New Mexico with Kiowa is remarkable, a very large number of stems and affixes having practically the same sound, while the grammar runs parallel throughout. Certain subtle and unusual phonetic hardenings occurring in these languages make it impossible to assume anything but common descent from a not very remote ancestral tongue. These discoveries open up far-reaching speculations and problems with regard to the origin of the Pueblo Indians.

In August Mr. Harrington proceeded to southern California, where he continued his studies of the Chumashan Indians, most of the time being devoted to the Ventureño, which was also the dialect most successfully studied. During the course of the work the last good informant on the language of La Purisima died. Important information was recorded on the ancient customs attending birth, marriage, and death, and some idea was gleaned of the manner of conducting primitive pre-Spanish fiestas. Data on native foods was also obtained, including detailed descriptions of the preparation of acorn and other vegetal foods in this region, information on these processes having never before been recorded. For example, in the preparation of acorns various species were employed, and also certain individual trees were noted for their preferable fruit, but the final palatableness of the acorn mush depended largely on the patience and skill of the woman who prepared it. A kind of acorn bread was also prepared by cooling the mush in small molds which were placed in running water. Certain other vegetal foods, as the pit of the islay or California wild cherry, required long and complicated preparation. As primitive beverages may be mentioned toasted chia or similar seeds stirred up with the fingers in cold water; a satisfying drink made by soaking the bark of the ash in water; blackberries crushed in water; and a drink prepared from the fruit of the manzanita. A delicious sugar was obtained from a species of reed, and the fruit of the juniper was ground into a sweet, yellowish food. Interesting snatches of information reveal the former plenitude of fish and game. Fishing paraphernalia was evi-

dently quite highly developed, both nets and harpoons having been in use, but the whale was not hunted, although the flesh of stranded whales was eagerly made use of.

Mr. Harrington returned to Washington at the close of May and spent the following month in the preparation of manuscript material.

SPECIAL RESEARCHES.

Dr. Franz Boas, honorary philologist, has been engaged in the correction of the proof of the Thirty-fifth Annual Report. Continued correspondence with Mr. George Hunt, of Fort Rupert, Vancouver Island, has added a considerable amount of new material to the original report.

Preparatory work for the discussion of the ethnology of the Kwa-kiutl Indians was also continued during the present year. A chapter on place names and another one on personal names and material for maps accompanying the chapters on place names has been submitted. Thanks are due to Dr. Edward Sapir, of the Geological Survey of Canada, through whose kindness the detailed surveys of the land office of British Columbia have been utilized. Other detailed maps showing the distribution of garden beds and charts illustrating the genealogies of a number of families have been prepared.

After the unfortunate death of Mr. Haeberlin, the work on the Salish material was transferred to Miss Helen H. Roberts, who, in the course of the year, completed the study of the basketry of the Salish Indians. A considerable amount of additional information, the need for which developed during the work, was supplied by Mr. James Teit, who, at Dr. Boas's request, and following detailed questions, reported on special aspects of the decorative art of the Thompson Indians. This work has been carried on with the continued financial support of Mr. Homer E. Sargent, whose interest in ethnological work in the Northwest has already furnished most important material. During the year the work on the map accompanying the discussion of the distribution of the Salish tribes was also completed.

Work on the second part of the Handbook of American Indian Languages also progresses. The completed sketches of the Alsea language, by Dr. Leo J. Frachtenberg, and that of the Paiute, by Dr. Edward Sapir, were received by the end of the preceding fiscal year, and the editorial work on these sketches has nearly been completed. These two sketches and that of the Kutenai, which has partly been written, will complete the second volume of the Handbook.

Dr. Walter Hough, curator of ethnology, was detailed to continue archeological work in the White Mountain Apache Reserve, Arizona,

on ruins reconnoitered in 1918. Dr. Hough was aided in his field work by Mr. and Mrs. S. W. Jacques, of Lakeside, by whom his work was much facilitated. Field work was especially devoted to the ruins called by the Apaches Nustegge Toega, "Grasshopper Spring," and clusters of sites in the near vicinity which form a very large group, indicating extensive intermingling of cultures. The main cluster stands in the open green valley and consists of two great heaps of stones covered with squaw bush, walnut, juniper, and pine, with occasional fragments of projecting walls, evidences of two large compact pueblos separated by Salt River draw. The west village (four or five stories high) has a court near the south end, 90 by 140 feet, connected with a small plaza, and covers more than an acre. The east village is more than half an acre in area. North of the west village is a plaza 300 feet long, flanked in part on the west by an isolated clan house of 18 rooms. The six ruins in the cluster that may be regarded as clan houses differ in size and arrangement of rooms and in general show considerable skill in construction. A third form of building west of the large village is indicated by large rectangular areas outlined with building stones scattered over the level ground. The foundations are of four or five courses, but never were buried more than 18 inches, indicating that they did not support a heavy superstructure. Two lenticular rubbish heaps, measuring 60 by 72 feet and 4 feet high, lie on the meadow 100 yards south of the walls of the large village. A feature of Pueblo masonry discovered here was retaining walls of quite large stone set on bedrock, apparently intended to counter lateral thrust of heavy walls. Several rooms were cleared out by Apache laborers under Dr. Hough's direction and many artifacts and some human skeletal material were obtained.

Mr. Neil M. Judd, curator of American archeology, prosecuted archeological field work in certain caves in Cottonwood Canyon which he had visited in 1915. He successfully investigated five prehistoric ruins in Cottonwood Canyon caves during the two weeks in which work was possible. Walls of houses were found to be built entirely of adobe, as well as the customary structures made of stone bound with clay mortar. Associated with these dwellings were rooms of still another type—houses whose walls consisted of vertical posts set at intervals and joined by masses of adobe. It will be noted that all three types closely resemble those structures exposed during the excavation of mounds in central Utah and previously reported.¹

The dwellings in "Kiva Cave" form the best preserved cliff village yet visited by Mr. Judd north and west of the Rio Colorado. Two of the four houses visited are practically intact; the ceremonial

¹ Smithsonian Misc. Coll., vol. 66, No. 3, pp. 64-69; No. 17, pp. 103-108; vol. 68, No. 12, p. 83.

chamber, from which the ruin takes its name, being in excellent condition, although constantly exposed to the snow and summer rains. After excavating this cave considerable restoration was attempted in order that walls weakened by action of the elements and by thoughtless visitors might be preserved for years to come. At the suggestion of Mr. B. A. Riggs a fence was constructed around the house to keep cattle from that portion of the cave.

Buildings with masonry walls were also found in "Ruin Cave," but in this case were built directly upon remains of other structures of an entirely different character. The latter are usually circular and their walls were formed of posts to which horizontal willows were bound at intervals of 7 or 8 inches; adobe mud was pressed between these posts and over the willows, but additional and larger supports were required to take the great weight of the roof. Although these structures lie generally beneath the stone houses, it is evident that both types were built by the same people and the occupancy of the cave was at no time long interrupted.

Prehistoric house remains were also found in each of the other three caves excavated, but they consisted chiefly of small rooms with walls constructed entirely of adobe. Still other ruins were discovered high up under the ledges that lie on either side of Cottonwood Canyon, but unusual conditions prevented examination of these.

Upright sandstone slabs invariably form the inner base of the walls in ruins throughout the region under consideration, a fact which connects them with the so-called "slab-house" people of the San Juan drainage. Whether there is, in fact, any justification for this term remains yet to be proven, but the cultural relationship of the prehistoric peoples in southwestern Utah with those south of the Rio Colorado is at last definitely established.

The bureau purchased from Miss Frances Densmore papers on "Chippewa Remedies and General Customs" and "Chippewa Art." The latter article has 164 pages, with 42 pages of old Chippewa designs and numerous photographs pertaining to industries, medicinal plants, customs, and toys of children, games, processes of weaving, tanning, and other industries. The lists of plants were identified by Mr. Paul C. Standley.

Miss Densmore likewise submitted much new manuscript material on the music of the Mandan, Hidatsa, and Pawnee. With this addition her account of the Mandan-Hidatsa music contains 340 pages, more than 40 illustrations, and two new forms of graphic representation of their progression. This article is now ready for publication.

An important field of aboriginal music thus far not sufficiently investigated is among the Pawnee. While engaged in the study of the music of this tribe at Pawnee, Okla., Miss Densmore witnessed a Hand Game, the Buffalo, Lance, and two Victory dances, and later

recorded on the phonograph the numerous songs sung at the three first gatherings. This material, with musical transcription tabulated and descriptive analyses, has been purchased by the bureau.

Dr. Aleš Hrdlička, curator of physical anthropology, was detailed to make an examination of the archeological remains of southwestern Florida, especially of the shell heaps along the coast south of Key Marco, a region very little explored by archeologists and one of the least known sections of that State. In spite of difficulties, Dr. Hrdlička's field work was successful. He visited several groups of shell heaps of large size as yet unrecorded and opened up a most instructive field for future exploration in a report which has been presented for publication. He also made highly important observations on physical features of the remnants of Indians that still inhabit the little known regions of Florida.

Mr. David I. Bushnell, jr., continued the preparation of manuscript for the Handbook of Aboriginal Remains East of the Mississippi, adding various notes to the manuscript. He likewise added about 30 pages to the manuscript entitled "Native Villages and Village Sites East of the Mississippi," now being printed as Bulletin 69. During the same period he completed a manuscript bearing the title "Native Cemeteries and Forms of Burial East of the Mississippi," which is to appear as Bulletin 71 of the bureau series.

With an allotment from the bureau Mr. Gerard Fowke has been engaged in special archeological investigations in the Ozark region of central Missouri. His careful detailed studies have been confined to the numerous caves in that region.

If "cave men," using this term to designate the predecessors of any race or tribe known to history, ever existed in the Mississippi Valley, we would find in no part of it natural features better adapted for his requirements than the Ozark Hills, but so far not the slightest trace of his presence has been revealed. Products of human industry have been reported as occurring under other conditions at great depths, even at the bottom of the loess, though in all such cases there is some uncertainty as to the correctness of the observations. On the contrary, whatever may be the depth of the deposit containing them, the artificial objects exhumed are uniform in character from top to bottom. The specimens found on the clay or solid rock floor are of the same class as those barely covered by the surface earth. Moreover, when they cease to appear they cease absolutely.

By careful search in the caves and rock shelters of which the Indian known to history availed himself extensive and interesting museum collections can be made. To find an earlier man it will be necessary to investigate caverns which he found suitable for occupancy and in which the accumulation of detritus, from whatever source, has been sufficient to cover his remains so deeply that they

can not be confused with those of a later period, and it may be necessary to discover with them bones of extinct animals. No examination of a cavern is complete unless a depth is reached where glacial deposits are undeniably of such age as to antedate the possible appearance of man upon the scene. The Ozark region promises important revelations in the study of prehistoric man in America.

Mr. Fowke has thoroughly investigated one of the caves in this region and has prepared an important report on his work which will later be published by the bureau. He has also transmitted to the National Museum a collection which is the largest yet obtained from this locality. The results of the work thus far are technical and can not be adequately stated in this place, but are not only very important additions to the archeology of the region investigated but also highly significant in comparative studies of ancient man in North America.

MANUSCRIPTS.

In addition to the manuscripts submitted for publication by the bureau there was also obtained by purchase an article by Mr. C. S. Simmons dealing with the Peyote religion.

EDITORIAL WORK AND PUBLICATIONS.

The editing of the publications of the bureau was continued through the year by Mr. Stanley Searles, assisted by Mrs. Frances S. Nichols. The status of the publications is presented in the following summary:

PUBLICATIONS ISSUED.

Thirty-second Annual Report.—Accompanying paper: Seneca Fiction, Legends, and Myths (Hewitt and Curtin).

Bulletin 59.—Kutenai Tales (Boas).

Bulletin 61.—Teton Sioux Music (Densmore).

Bulletin 64.—The Maya Indians of Southern Yucatan and Northern British Honduras (Gann).

Bulletin 65.—Archæological Explorations in Northeastern Arizona (Kidder and Guernsey).

Bulletin 66.—Recent Discoveries of Remains Attributed to Early Man in America (Hrdlička).

List of publications of the bureau.

Introduction to Seneca Fiction, Legends, and Myths (Hewitt).—From *Thirty-second Annual Report* (Hewitt and Curtin).

PUBLICATIONS IN PRESS OR IN PREPARATION.

Thirty-third Annual Report.—Accompanying papers: (1) Uses of Plants by the Indians of the Missouri River Region (Gilmore); (2) Preliminary Account of the Antiquities of the Region between the Mancos and La Plata Rivers in Southwestern Colorado (Morris); (3) Designs on Prehistoric Hopi Pottery (Fewkes); (4) The Hawaiian Romance of Laleikawai (Beckwith).

Thirty-fourth Annual Report.—Accompanying paper: Prehistoric island culture areas of America (Fewkes).

Thirty-fifth Annual Report.—Accompanying paper: Ethnology of the Kwakiutl (Boas).

Thirty-sixth Annual Report.—Accompanying paper: Early History of the Creek Indians and their Neighbors (Swanton).

Bulletin 40.—Part 2: Handbook of American Indian Languages (Boas).

Bulletin 60.—Handbook of Aboriginal American Antiquities: Part 1, Introduction; The Lithic Industries (Holmes).

Bulletin 67.—Alsea Texts and Myths (Frachtenberg).

Bulletin 68.—Structural and Lexical Comparison of the Tunica, Chitimacha, and Atakapa Languages (Swanton).

Bulletin 69.—Native Villages and Village Sites East of the Mississippi (Bushnell).

Bulletin 70.—Prehistoric Villages, Castles, and Towers (Fewkes).

Bulletin 71.—Native Cemeteries and Forms of Burial East of the Mississippi (Bushnell).

DISTRIBUTION OF PUBLICATIONS.

The distribution of the publications has been continued under the immediate charge of Miss Helen Munroe, assisted by Miss Emma B. Powers.

Publications were distributed as follows:

Reports and separates.....	2,742
Bulletins and separates.....	8,440
Contributions to North American Ethnology.....	10
Introductions.....	10
Miscellaneous	281
	<hr/>
	11,483

As compared with the fiscal year 1918, there was an increase of 4,139 publications distributed. This was doubtless due to the fact that whereas in the fiscal year 1918 only Bulletin 63 was distributed to the mailing list, during the fiscal year 1919 there were distributed to the list Bulletins 59, 61, 64, and 66, and the Thirty-second Annual Report. Fourteen addresses have been added to the mailing list during the year and 36 dropped, making a net decrease of 22.

ILLUSTRATIONS.

Mr. DeLancey Gill, with the assistance of Mr. Albert E. Sweeney, continued the preparation of the illustrations of the bureau and gave the usual time to photography of visiting Indians. A summary of this work follows:

Negatives for publication work.....	138
Negative films exposed in field.....	228
Photographic prints.....	603
Photostat copies.....	128
Drawings for publication.....	200
Illustrations made ready for engraving.....	2,000
Engraved proofs edited.....	310
Colored illustrations inspected at Government Printing Office.....	10,000

LIBRARY.

The reference library continued in the immediate charge of Miss Ella Leary, assisted by Mr. Charles B. Newman, who was absent a short time in the military service.

During the year 380 books were accessioned, of which 90 were acquired by purchase, 160 by gifts and exchange, and 130 by the entry of newly bound volumes of periodicals previously received. The periodicals currently received number about 760, of which 25 were received by subscription and 735 through exchange. In addition, the bureau acquired 210 pamphlets. The aggregate number of books in the library at the close of the year was 22,560; of pamphlets, about 14,248. In addition, there were many volumes of unbound periodicals. The publication of various European periodicals devoted to anthropology has either been suspended or has ceased.

The number of books bound during the year was 350. It has been almost exclusively work upon the current material—serials grouped into volumes and new accessions in paper covers.

Correspondence relative to new exchanges and missing parts of serial publications already in the library was carried on as in previous years. Considerable time was given to research work, which frequently calls for the preparation of bibliographic lists for correspondents.

In addition to the use of its own library, it was found necessary to draw on the Library of Congress from time to time for the loan of about 400 volumes. The Library of Congress, officers of the executive departments, and out-of-town students have made use of the library through frequent loans during the course of the year.

The need by the library of additional shelf room is becoming more and more acute. Each day the congestion increases. We have filled almost every available foot of shelf space and we are sorely in need of more room.

The recataloguing of books from the old author (card) catalogue to a new subject catalogue has continued, and as a result the year shows a marked increase in the total of cards filed in the catalogue records.

The Monthly Bulletin for the use of the bureau has been continued throughout the year.

COLLECTIONS.

The following collections acquired by members of the staff of the bureau, or by those detailed in connection with its researches, have been transferred to the United States National Museum:

Two skeletons with skulls, found on the property of the Roxana Petroleum Co. of Oklahoma, South Wood River, Ill., and presented by it to this bureau. (62630.)

Twelve prehistoric pottery heads found in Huastec mounds and presented to Dr. J. Walter Fewkes by Mr. John M. Muir, of Tampico, Mexico. (62931.)

Thirty-one archeological specimens obtained by Mr. F. W. Hodge at Hawikuh, N. Mex., in 1917, as part of the cooperative work of the Bureau of American Ethnology and the Museum of the American Indian (Heye Foundation). (63154.)

Forty archeological specimens and an Indian skull, from different localities in Arizona; collected for the bureau by Dr. Walter Hough in 1918. (63156.)

Two hundred and eighty-eight archeological specimens and two lots of skeletal material, from Gourd Creek, Mo.; collected by Gerard Fowke in 1918. (63157.)

A specimen of slag with embedded charred corn; collected by Dr. J. Walter Fewkes, from a ruin in Mancos Valley, 3 miles west of the bridge on the Cortez-Ship Rock Road, Colorado. (63174.)

Sandstone pipe found on Black Warrior River, Tuscaloosa County, Ala., and presented to the bureau by Mr. F. H. Davis, United States Engineer's Office, Little Rock, Ark. (63509.)

Pillar stone found at Cerro Cebadilla, Vera Cruz; gift of Dr. H. Adrian, Tampico, Mexico. (63523.)

Three well-made clay heads from the neighborhood of Panuco, Mexico; gift of Mr. John M. Muir. (63524.)

PROPERTY.

Furniture was purchased to the amount of \$128.76. The cost of typewriting machines was \$143.40, making a total of \$272.16.

MISCELLANEOUS.

Clerical.—The correspondence and other clerical work of the office, including the copying of manuscripts, has been conducted by Miss May S. Clark, clerk to the chief. Mrs. Frances S. Nichols assisted the editor.

There has been no change in the scientific or clerical force.
Respectfully submitted.

J. WALTER FEWKES, *Chief.*

Dr. CHARLES D. WALCOTT,

Secretary Smithsonian Institution.

12573°—21—5

APPENDIX 3.

REPORT ON THE INTERNATIONAL EXCHANGES.

SIR: I have the honor to submit the following report on the operations of the International Exchange Service during the fiscal year ending June 30, 1919:

The institution submitted to Congress an estimate of \$35,000 for carrying on the service during the year. This amount was granted. In addition, Congress, at the request of the institution, reappropriated the unexpended balance of the 1918 appropriation, amounting to \$712.90, together with the additional sum of \$903.68, for payment of liabilities incurred in the maintenance of the service during the current fiscal year over and above the amount of the regular congressional appropriation. Congress also made the usual allotment of \$200 for printing and binding. The repayments from departmental and other establishments aggregated \$1,808.87, making the total available resources for carrying on the system of exchanges during the fiscal year 1919, \$38,625.45.

During the year 1919 the total number of packages handled was 270,860—an increase over the number for the preceding year of 3,914. The weight of these packages was 291,918 pounds—a gain of 109,093 pounds. This large increase in weight as compared with the small increase in the number of packages is accounted for, in part, by the consignments received for transmission to establishments in France and Belgium whose libraries were destroyed during the war, and, in part, by the accumulations of United States patent specifications received for Great Britain, Belgium, and the northern neutrals. The former were forwarded in boxes unopened, each box being counted as one package only, and the latter consisted entirely of heavy packages.

The publications sent and received by the exchange service are classified under three heads: (1) "Parliamentary documents"; (2) "Departmental documents"; (3) "Miscellaneous scientific and literary publications."

The term "parliamentary documents," as here used, refers to publications set aside by act of Congress for exchange with foreign Governments, and includes not only documents printed by order of either House of Congress, but also copies of each publication issued by any department, bureau, commission, or officer of the Government. The Governments to which this class of publications are forwarded send to this country in exchange copies of their own official documents for deposit in the Library of Congress.

The term "departmental documents" embraces all of the publications delivered at the institution by the various governmental departments, bureaus, or commissions for distribution to their correspondents abroad, the publications received in return being deposited in the various departmental libraries.

The "miscellaneous scientific and literary publications" are received chiefly from learned societies, universities, colleges, scientific institutions, and museums in the United States for transmission to similar establishments in all parts of the world.

The number and weight of the packages of different classes are indicated in the following table:

	Packages.		Weight.	
	Sent.	Received.	Sent.	Received.
			<i>Pounds.</i>	<i>Pounds.</i>
United States parliamentary documents sent abroad...	151,307	.....	83,692	.....
Publications received in return for parliamentary documents.....		1,335		3,100
United States departmental documents sent abroad...	65,892	.....	103,295	.....
Publications received in return for departmental documents.....		3,918		2,630
Miscellaneous scientific and literary publications sent abroad.....	40,188	.....	82,267	.....
Miscellaneous scientific and literary publications received from abroad for distribution in the United States.....		8,220		16,934
Total.....	257,387	13,473	269,254	22,664
Grand total.....	270,860		291,918	

It should be stated in this connection that the disparity indicated by the foregoing statistics between the number of packages sent and those received is accounted for, in part, by the fact that packages transmitted abroad contain, as a rule, only one publication, while those received in return often comprise many volumes. In some instances, especially in the case of publications received in exchange for parliamentary documents, the term "package" is applied to large boxes containing many separate publications. Furthermore, many returns for publications sent abroad reach their destinations through the mail and not through the exchange service.

Under date of September 12, 1918, the Dutch Exchange Bureau reported that five boxes sent by the institution to that bureau in January, 1917, had been lost at sea when the steamship by which they were being forwarded was torpedoed by the enemy. So far as reported, this is the fourth instance in which consignments sent to foreign countries by the institution have been lost through hostile action.

It has not yet been possible to put the service on a prewar basis so far as the forwarding of consignments abroad is concerned. Ship-

ments in boxes are being made as frequently as present conditions will permit to all countries except Austria, Bulgaria, Germany, Hungary, Montenegro, Roumania, Russia, Serbia, and Turkey. It is not thought advisable to forward consignments to these until the peace treaties with the enemy countries are finally ratified by the United States Government and internal conditions become more settled. It is hoped that in the early part of the next fiscal year it will be possible to make shipments to all countries.

To some countries transmissions were not wholly suspended for any long period during the war. However, as was to be expected during such abnormal times, the institution met with many obstacles in its efforts to keep the exchanges open. The charge for ocean freight grew to great proportions. The rate to England, for instance, at one time reached \$5.80 per cubic foot. The charge on shipments to that country before the war was \$0.16 a cubic foot, thus making the increase more than thirty-sixfold. Such rates becoming too exorbitant, the sending of packages in boxes was discontinued, and the mails were resorted to. Late in the fiscal year, when shipments were resumed to Belgium and the northern neutrals, the office was almost swamped with packages which had been accumulating for those countries for many months.

The chief of the Belgian Service of International Exchanges, in reply to a letter addressed to him early in February asking if his bureau was in a position to resume the distribution of exchanges, stated that there were no longer any obstacles to the renewal of the relations which had been interrupted on account of the encirclement of iron and fire in which his country found itself during the war. He added:

I should fail most lamentably in my duty, Mr. Secretary, if I did not add to this reply warm thanks in the name of the Belgian Government, in the name of our scientific establishments and institutions, and in my own name, for the extreme kindness which you have shown us in reserving for us until the present time, all the numerous "series" and "collections," one and all of inestimable value, which the war has prevented you from transmitting to us at the proper time.

Applications for permission to forward publications abroad through the service are being received from time to time, both from new and long-established institutions. As an illustration of appreciation of the value of the service by such organizations, may be quoted the following extract from a communication from the New York State College of Forestry at Syracuse, acknowledging the receipt of the Institution's letter extending the exchange facilities to that college:

It will mean a good deal to us in developing the exchange of publications for the forest library of this college.

Reference was made in last year's report to the steps being taken by the institution to procure for the war library and museum of the French Government at Paris copies of American documents, and other material relating to the war, for deposit in a section of that library, to be devoted to the part taken by the United States in the conflict. A similar request for posters was received during the year from the British War Museum, and as complete sets of posters as it was possible to procure, have been transmitted to that museum. A number of requests for publications issued in this country were received from other foreign establishments, and in each instance the institution endeavored to comply therewith.

The secretary of the institution took special steps to assist in the rehabilitation of the library of the Society of Sciences, Lille, France, whose collections were destroyed during the war. As a result of his efforts, several hundred publications were received for transmission to that library through the Exchange Service.

During the fiscal year 1919, 803 boxes were forwarded to foreign agencies for distribution, being an increase of 360 over the preceding 12 months. Notwithstanding this increase in the number of boxes sent, the total number is still far below the average for a normal year. This is due, in part, to the fact that shipments in boxes were suspended until the 1st of February. Up to that date packages were sent to their destinations by mail.

The dates of transmission of the 803 boxes forwarded to foreign countries are shown in the following table. Of these boxes 260 contained full sets of United States official documents for authorized depositories:

Consignments of exchanges for foreign countries.

Country.	Number of boxes.	Date of transmission.
Argentina.....	19	Apr. 8, 1919.
Belgium.....	72	Apr. 29, 1919.
Bolivia.....	2	Mar. 28, 1919.
Brazil.....	15	Feb. 8, Apr. 5, 1919.
British colonies.....	5	Apr. 29, June 12, 1919.
British Guiana.....	1	Mar. 27, 1919.
Canada.....	24	Sept. 26, 1918; Jan. 27, Mar. 25, Apr. 21, May 17, June 6, 1919.
Chile.....	9	Apr. 3, 1919.
China.....	8	Jan. 20, 1918; Feb. 23, Mar. 25, May 28, 1919.
Colombia.....	6	Mar. 31, 1919.
Costa Rica.....	8	Apr. 4, 1919.
Cuba.....	6	Sept. 26, 1918; Jan. 27, Mar. 25, Apr. 21, May 17, June 6, 1919.
Denmark.....	21	Feb. 19, 1919.
Ecuador.....	3	Mar. 4, 1919.
Egypt.....	14	Apr. 10, 1919.
France.....	57	Feb. 8, May 5, 1919.
Great Britain and Ireland.....	196	Feb. 5, Mar. 12, 25, May 12, June 2, 12, 1919
Guatemala.....	2	Mar. 28, 1919.

Consignments of exchanges for foreign countries—Continued.

Country.	Number of boxes.	Date of transmission.
Haiti.....	5	Apr. 9, 1919.
Honduras.....	2	Mar. 4, 1919.
India.....	24	Feb. 12, June 19, 1919.
Italy.....	31	June 17, 1919.
Jamaica.....	4	Mar. 26, 1919.
Japan.....	20	Apr. 16, 1919.
Mexico.....	6	Sept. 26, 1918; Jan. 27, Mar. 25, Apr. 21, May 17, June 6, 1919.
Netherlands.....	54	Mar. 11, June 30, 1919.
Nicaragua.....	1	Mar. 28, 1919.
Norway.....	20	Feb. 19, 1919.
Paraguay.....	2	Mar. 28, 1919.
Peru.....	6	Apr. 2, 1919.
Queensland.....	8	Feb. 5, May 12, June 12, 1919.
Salvador.....	2	Mar. 28, 1919.
Spain.....	15	Apr. 22, 1919.
Sweden.....	53	Feb. 25, 1919.
Switzerland.....	25	June 30, 1919.
Tasmania.....	9	Feb. 5, May 12, June 12, 1919.
Union of South Africa.....	15	June 26, 1919.
Uruguay.....	7	Apr. 1, 1919.
Venezuela.....	5	Mar. 31, 1919.
Victoria.....	11	Feb. 13, 1919.
Western Australia.....	10	Feb. 5, May 12, June 12, 1919.

FOREIGN DEPOSITORIES OF UNITED STATES GOVERNMENTAL DOCUMENTS.

Ninety-one sets of United States governmental documents (55 full sets and 36 partial sets) were received for distribution in accordance with treaty stipulations and under the authority of the congressional resolutions of March 2, 1867, and March 2, 1901.

A complete list of the foreign depositories is given below. Consignments for those countries to which shipments were suspended on account of the war will be forwarded to the various depositories as soon as the peace treaties are ratified by the United States Government.

DEPOSITORIES OF FULL SETS.

ARGENTINA: Ministerio de Relaciones Exteriores, Buenos Aires.

AUSTRALIA: Library of the Commonwealth Parliament, Melbourne.

AUSTRIA: K. K. Statistische Zentral-Kommission, Vienna.

BADEN: Universitäts-Bibliothek, Freiburg. (Depository of the Grand Duchy of Baden.)

BAVARIA: Königl. Hof- und Staats-Bibliothek, Munich.

BELGIUM: Bibliothèque Royale, Brussels.

BRAZIL: Biblioteca Nacional, Rio de Janeiro.

BUENOS AIRES: Biblioteca de la Universidad Nacional de La Plata. (Depository of the Province of Buenos Aires.)

CANADA: Library of Parliament, Ottawa.

CHILE: Biblioteca del Congreso Nacional, Santiago.

- CHINA:** American-Chinese Publication Exchange Department, Shanghai Bureau of Foreign Affairs, Shanghai.
- COLOMBIA:** Biblioteca Nacional, Bogotá.
- COSTA RICA:** Oficina de Depósito y Canje Internacional de Publicaciones, San José.
- CUBA:** Secretaria de Estado (Asuntos Generales y Canje Internacional), Habana.
- DENMARK:** Kongelige Bihliotheket, Copenhagen.
- ENGLAND:** British Museum, London.
- FRANCE:** Bibliothèque Nationale, Paris.
- GERMANY:** Deutsche Reichstags-Bibliothek, Berlin.
- GLASGOW:** City Librarian, Mitchell Library, Glasgow.
- GREECE:** Bibliothèque Nationale, Athens.
- HAITI:** Secrétaire d'État des Relations Extérieures, Port au Prince.
- HUNGARY:** Hungarian House of Delegates, Budapest.
- INDIA:** Imperial Library, Calcutta.
- IRELAND:** National Library of Ireland, Dublin.
- ITALY:** Biblioteca Nazionale Vittorio Emanuele, Rome.
- JAPAN:** Imperial Library of Japan, Tokyo.
- LONDON:** London School of Economics and Political Science. (Depository of the London County Council.)
- MANITOBA:** Provincial Library, Winnipeg.
- MEXICO:** Instituto Bibliográfico, Biblioteca Nacional, Mexico.
- NETHERLANDS:** Bibliotheek van der Staten-Generaal, The Hague.
- NEW SOUTH WALES:** Public Library of New South Wales, Sydney.
- NEW ZEALAND:** General Assembly Library, Wellington.
- NORWAY:** Storthingets Bibliothek, Christiania.
- ONTARIO:** Legislative Library, Toronto.
- PARIS:** Préfecture de la Seine.
- PERU:** Biblioteca Nacional, Lima.
- PORTUGAL:** Biblioteca Nacional, Lisbon.
- PRUSSIA:** Königliche Bibliothek, Berlin.
- QUEBEC:** Library of the Legislature of the Province of Quebec, Quebec.
- QUEENSLAND:** Parliamentary Library, Brisbane.
- RUSSIA:** Imperial Public Library, Petrograd.
- SAXONY:** Königliche Oeffentliche Bibliothek, Dresden.
- SERBIA:** Section Administrative du Ministère des Affaires Étrangères, Belgrade.
- SOUTH AUSTRALIA:** Parliamentary Library, Adelaide.
- SPAIN:** Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.
- SWEDEN:** Kungliga Biblioteket, Stockholm.
- SWITZERLAND:** Bibliothèque Fédérale Centrale, Berne.
- TASMANIA:** Parliamentary Library, Hobart.
- TURKEY:** Department of Public Instruction, Constantinople.
- UNION OF SOUTH AFRICA:** State Library, Pretoria, Transvaal.
- URUGUAY:** Oficina de Canje Internacional de Publicaciones, Montevideo.
- VENEZUELA:** Biblioteca Nacional, Caracas.
- VICTORIA:** Public Library of Victoria, Melbourne.
- WESTERN AUSTRALIA:** Public Library of Western Australia, Perth.
- WÜRTTEMBERG:** Königliche Landesbibliothek, Stuttgart.

DEPOSITORIES OF PARTIAL SETS.

- ALBERTA:** Provincial Library, Edmonton.
- ALSACE-LORRAINE:** K. Ministerium für Elsass-Lothringen, Strassburg.
- BOLIVIA:** Ministerio de Colonización y Agricultura, La Paz.

BREMEN: Senatskommission für Reichs- und Auswärtige Angelegenheiten.
BRITISH COLUMBIA: Legislative Library, Victoria.
BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.
BULGARIA: Minister of Foreign Affairs, Sofia.
CEYLON: Colonial Secretary's Office (Record Department of the Library), Colombo.
ECUADOR: Biblioteca Nacional, Quito.
EGYPT: Bibliothèque Khédiviale, Cairo.
FINLAND: Chancery of Governor, Helsingfors.
GUATEMALA: Secretary of the Government, Guatemala.
HAMBURG: Senatskommission für die Reichs- und Auswärtigen Angelegenheiten.
HESSE: Grossherzogliche Hof-Bibliothek, Darmstadt.
HONDURAS: Secretary of the Government, Tegucigalpa.
JAMAICA: Colonial Secretary, Kingston.
LIBERIA: Department of State, Monrovia.
LOURENÇO MARQUEZ: Government Library, Lourenço Marquez.
LÜBECK: President of the Senate.
MADRAS, PROVINCE OF: Chief Secretary to the Government of Madras, Public Department, Madras.
MALTA: Lieutenant Governor, Valetta.
MONTENEGRO: Ministère des Affaires Étrangères, Cetinje.
NEW BRUNSWICK: Legislative Library, Fredericton.
NEWFOUNDLAND: Colonial Secretary, St. John's.
NICARAGUA: Superintendente de Archivos Nacionales, Managua.
NORTHWEST TERRITORIES: Government Library, Regina.
NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.
PANAMA: Secretaria de Relaciones Exteriores, Panama.
PARAGUAY: Oficina General de Inmigracion, Asuncion.
PRINCE EDWARD ISLAND: Legislative Library, Charlottetown.
ROUMANIA: Academia Romana, Bucharest.
SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.
SIAM: Department of Foreign Affairs, Bangkok.
STRAITS SETTLEMENTS: Colonial Secretary, Singapore.
UNITED PROVINCES OF AGRA AND OUDH: Under Secretary to Government, Allahabad.
VIENNA: Bürgermeister der Haupt- und Residenz-Stadt.

INTERPARLIAMENTARY EXCHANGE OF OFFICIAL JOURNALS.

The Governments named below have entered into the interparliamentary exchange of official journals with the United States and are listed to receive copies of the daily issue of the Congressional Record:

Argentine Republic.	France.	Prussia.
Australia.	Great Britain.	Queensland.
Austria.	Greece.	Roumania.
Baden.	Guatemala.	Russia.
Belgium.	Honduras.	Serbia.
Bolivia.	Hungary.	Spain.
Brazil.	Italy.	Switzerland.
Buenos Aires, Province of.	Liberia.	Transvaal.
Canada.	New South Wales.	Union of South Africa.
Costa Rica.	New Zealand.	Uruguay.
Cuba.	Peru.	Venezuela.
Denmark.	Portugal.	Western Australia.

FOREIGN EXCHANGE AGENCIES.

A letter was received in April, 1919, from the director of the National Library in Lisbon, stating that the general secretariat of the Library and National Archives had been abolished and that the Service of International Exchanges, created by the Brussels Convention of March 15, 1886, is now conducted under the direction of his library.

Below is given a complete list of the foreign exchange agencies or bureaus. Shipments to those countries marked with an asterisk were still suspended at the close of the fiscal year.

ALGERIA, *via* France.

ANGOLA, *via* Portugal.

ARGENTINA: Comisión Protectora de Bibliotecas Populares, Lavalle 1216, Buenos Aires.

AUSTRIA: * K. K. Statistische Zentral-Kommission, Vienna.

AZORES, *via* Portugal.

BELGIUM: Service Belge des Échanges Internationaux, Rue des Longs-Chariots 46, Brussels.

BOLIVIA: Oficina Nacional de Estadística, La Paz.

BRAZIL: Serviço de Permutações Internacionais, Bibliotheca Nacional, Rio de Janeiro.

BRITISH COLONIES: Crown Agents for the Colonies, London.

BRITISH GUIANA: Royal Agricultural and Commercial Society, Georgetown.

BRITISH HONDURAS: Colonial Secretary, Belize.

BULGARIA: * Institutions Scientifiques de S. M. le Roi de Bulgarie, Sofia.

CANARY ISLANDS, *via* Spain.

CHILE: Servicio de Canjes Internacionales, Biblioteca Nacional, Santiago.

CHINA: American-Chinese Publication Exchange Department, Shanghai Bureau of Foreign Affairs, Shanghai.

COLOMBIA: Oficina de Canjes Internacionales y Reparto, Biblioteca Nacional, Bogotá.

COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.

DENMARK: Kongelige Danske Videnskabernes Selskab, Copenhagen.

DUTCH GUIANA: Surinaamsche Koloniale Bibliotheek, Paramaribo.

ECUADOR: Ministerio de Relaciones Exteriores, Quito.

EGYPT: Government Publications Office, Printing Department, Bulaq, Cairo.

FRANCE: Service Français des Échanges Internationaux, 110 Rue de Grenelle, Paris.

GERMANY: * Amerika-Institut, Berlin, N. W. 7.

GREAT BRITAIN AND IRELAND: Messrs. William Wesley & Son, 28 Essex Street, Strand, London.

GREECE: Bibliothèque Nationale, Athens.

GREENLAND, *via* Denmark.

GUADELOUPE, *via* France.

GUATEMALA: Instituto Nacional de Varones, Guatemala.

GUINEA, *via* Portugal.

HAITI: Secrétaire d'État des Relations Extérieures, Port au Prince.

HONDURAS: Biblioteca Nacional, Tegucigalpa.

ICELAND, *via* Denmark.

INDIA: Superintendent of Stationery, Bombay.

ITALY: Ufficio degli Scambi Internazionali, Biblioteca Nazionale Vittorio Emanuele, Rome.

JAMAICA: Institute of Jamaica, Kingston.

JAPAN: Imperial Library of Japan, Tokyo.

JAVA, *via* Netherlands.

KOREA: Government General, Keijo.

LIBERIA: Bureau of Exchanges, Department of State, Monrovia.

LOURENÇO MARQUEZ: Government Library, Lourenço Marquez.

LUXEMBURG, *via* Germany.

MADAGASCAR, *via* France.

MADEIRA, *via* Portugal.

MONTENEGRO:* Ministère des Affaires Étrangères, Cetinge.

MOZAMBIQUE, *via* Portugal.

NETHERLANDS: Bureau Scientifique Central Néerlandais, Bibliothèque de l'Université, Leyden.

NEW GUINEA, *via* Netherlands.

NEW SOUTH WALES: Public Library of New South Wales, Sydney.

NEW ZEALAND: Dominion Museum, Wellington.

NICARAGUA: Ministerio de Relaciones Exteriores, Managua.

NORWAY: Kongelige Norske Frederiks Universitet Bibliotheket, Christiania.

PANAMA: Secretaria de Relaciones Exteriores, Panama.

PARAGUAY: Servicio de Canje Internacional de Publicaciones Sección Consular y de Comercio, Ministerio de Relaciones Exteriores, Asuncion.

PERSIA: Board of Foreign Missions of the Presbyterian Church, New York City.

PERU: Oficina de Reparto, Depósito y Canje Internacional de Publicaciones, Ministerio de Fomento, Lima.

PORTUGAL: Serviço de Permutações Internacionais, Bibliotheca Nacional, Lisbon.

QUEENSLAND: Bureau of Exchanges of International Publications, Chief Secretary's Office, Brisbane.

ROUMANIA:* Academia Romana, Bucharest.

RUSSIA:* Commission Russe des Échanges Internationaux, Bibliothèque Impériale Publique, Petrograd.

SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.

SERBIA:* Section Administrative du Ministère des Affaires Etrangères, Belgrade.

SIAM: Department of Foreign Affairs, Bangkok.

SOUTH AUSTRALIA: Public Library of South Australia, Adelaide.

SPAIN: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.

SUMATRA, *via* Netherlands.

SWEDEN: Kongliga Svenska Vetenskaps Akademien, Stockholm.

SWITZERLAND: Service des Échanges Internationaux, Bibliothèque Fédérale Centrale, Berne.

SYRIA: Board of Foreign Missions of the Presbyterian Church, New York.

TASMANIA: Secretary to the Premier, Hobart.

TRINIDAD: Royal Victoria Institute of Trinidad and Tobago, Port-of-Spain.

TUNIS, *via* France.

TURKEY:* American Board of Commissioners for Foreign Missions, Boston.

UNION OF SOUTH AFRICA: Government Printing Works, Pretoria, Transvaal.

URUGUAY: Oficina de Canje Internacional, Montevideo.

VENEZUELA: Biblioteca Nacional, Caracas.

VICTORIA: Public Library of Victoria, Melbourne.

WESTERN AUSTRALIA: Public Library of Western Australia, Perth.

WINDWARD AND LEEWARD ISLANDS: Imperial Department of Agriculture,
Bridgetown, Barbados.

PERSONNEL.

With his appointment as assistant secretary of the Smithsonian Institution on December 16, 1918, Dr. Charles G. Abbot was assigned to general charge of the international exchanges and the library in addition to the directorship of the Astrophysical Observatory.

Respectfully submitted.

C. G. ABBOT,
Assistant Secretary,
In Charge of Library and Exchanges.

DR. CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

APPENDIX 4.

REPORT ON THE NATIONAL ZOOLOGICAL PARK.

SIR: I have the honor to submit the following report on the operations of the National Zoological Park for the fiscal year ending June 30, 1919:

Recognizing the increased cost of maintenance, Congress allowed in the sundry civil bill the sum of \$115,000 for the expenses of the park, with an additional allotment of \$200 for printing and binding. This was an increase of \$15,000 over the appropriation for the preceding years. By the practice of great economy in all departments a small amount was made available from this sum for minor permanent improvements, and some long-needed work was accomplished during the year. Several of the employees who were in the military or naval service during the war returned to their duties at the park near the close of the year, and there is at present no distinct shortage of help except in the buildings and grounds department. The popularity of the Zoological Park continues to increase, and the number of visitors admitted to the grounds greatly exceeded that of any previous year. An attendance of nearly 2,000,000 was recorded. Notwithstanding the scarcity of help during the first months of the year, the buildings have been kept in a fair state of repair and the grounds are in a very good condition. The collection has been kept near normal size, with even slight increase in the number of specimens, and with no serious gaps or empty quarters. This is due almost entirely to the constant and efficient care of the employees in the animal department, with the resulting good condition and low death rate among their charges. The embargo on living animals during the war virtually prohibited importations, and only a few animals were received directly from foreign ports.

ACCESSIONS.

Gifts.—Animals to the number of 74 were accessioned during the year as gifts from friends of the park or were placed on indefinite deposit.

Two young Sumatran elephants received from the Smithsonian Institution were the most important and valuable additions to the collection. These were purchased at a cost of \$5,000 for the children

of Washington by a number of their friends and were donated to the institution. At the time of their arrival they were about 2 and 2½ years old and were 42 and 45 inches high. The Sumatran elephant had never before been exhibited in Washington. It is closely allied to the elephant of India, and differs from the African elephant in many characters, most conspicuous of which is the very small size of the ear. No specimen of this group of elephants has been in the collection since the death in March, 1917, of the old Indian elephant, "Dunk." The Sumatran elephant is said to average somewhat smaller than the elephant from British India, but the Dutch trader who accompanied these young animals from Sumatra reports having killed one which was 10 feet high at the shoulder. The baby elephants are already great favorites with the children and are growing rapidly. They are known by their Malayan names of "Hitam" (black) and "Kechil" (small).

Other particularly valuable donations were a fine capybara from Hon. Henry D. Baker, Trinidad, British West Indies, who has presented the park with other interesting specimens in past years; and a pair of Florida bears from Mrs. A. V. N. Stroop, Moore Haven, Fla. The capybara is an especially good specimen of this largest of all living rodents, and the Florida bear has never before been shown in the collection. The bears are still young, but will apparently grow to a much larger size than the common American black bears, as they are now considerably larger than Virginia specimens of approximately the same age, and the bears of Florida are known sometimes to exceed in size all other forms of the black bear.

Among the birds presented during the year the most important is an example of the great white heron of southern Florida, taken from the nest on one of the Newfound Harbor group of keys, Florida, May 12, 1919, by Dr. Paul Bartsch. This bird has developed splendidly and forms one of the unique exhibits of the bird department.

The complete list of donors and gifts is as follows:

- Hon. Henry D. Baker, Trinidad, British West Indies, capybara.
- Miss Marjorie Bandelaute, Washington, D. C., alligator.
- Dr. Paul Bartsch, Washington, D. C., great white heron.
- Mr. J. E. Boyle, Washington, D. C., horned toad.
- Mr. Morris K. Brady, Washington, D. C., alligator.
- Miss Eddie Capps, Schuyler, Va., alligator.
- Mr. Frederick Chester, Washington, D. C., alligator.
- Mr. E. R. Claud, Washington, D. C., horned toad.
- Mrs. V. Cook, Savannah, Ga., alligator.
- Mr. W. R. Coon, Washington, D. C., alligator.
- Miss Pauline Corson, Guinea Mills, Va., four gray foxes.
- Mr. Lee Cummins, Washington, D. C., two alligators.
- Mr. A. H. Davin, Palmyra, Va., five turtle doves.

Miss Elisabeth T. Davidson, Baltimore, Md., two grass paroquets.
 Mr. D. L. Du Pre, Washington, D. C., American barn owl.
 Mr. L. A. Ehrmantraut, Washington, D. C., chicken-guinea hybrid.
 Mr. W. H. Fairchild, Washington, D. C., red fox.
 Mr. J. F. E. Fields, Hancock, Md., banded rattlesnake.
 Mr. F. F. Gillen, Washington, D. C., three screech owls.
 Mrs. Lillie M. Glover, Washington, D. C., Isle of Pines parrot.
 Mrs. Gregory, Washington, D. C., Virginia opossum.
 Mrs. S. M. Hesey, Edinburg, Va., Cuban parrot.
 Mr. Charles P. Higgins, Washington, D. C., alligator.
 Mr. John B. Laing, Lewisburg, W. Va., black bear.
 Mr. Edward L. Latimer, Hyattsville, Md., great horned owl.
 Mr. Maynadiers, Washington, D. C., Virginia opossum.
 Mr. W. L. McAtee, Washington, D. C., rainbow snake.
 Mr. J. C. Meyer, Washington, D. C., three canary birds.
 Mr. H. D. Money, jr., Gulfport, Miss., two fox squirrels.
 Mr. James Mooney, jr., Washington, D. C., alligator.
 Mrs. C. P. Moore, Washington, D. C., alligator.
 Mr. Joseph G. Moore, Flint Hill, Va., two woodchucks.
 Mr. Charles A. Mosier, Holmstead, Fla., moccasin snake.
 Mr. R. E. Otterback, Washington, D. C., black snake.
 Mr. A. J. Poole, Washington, D. C., water snake.
 Mr. G. R. Putnam, Washington, D. C., horned toad.
 Mr. T. M. Quill, Washington, D. C., alligator.
 Mr. E. S. Schmid, Washington, D. C., spider monkey.
 Dr. R. W. Shufeldt, Washington, D. C., water snake, garter snake, snapping turtle, Florida terrapin, and two gopher tortoises.
 Maj. Walter L. Simpson, Washington, D. C., badger.
 Smithsonian Institution, Washington, D. C., two Sumatran elephants.
 Mr. J. F. Stowell, Washington, D. C., alligator.
 Mr. Blanford Straughn, Washington, D. C., chameleon.
 Mrs. A. V. N. Stroop, Moore Haven, Fla., two Florida bears.
 Mrs. Griffith E. Taylor, Berryville, Va., double yellow-head parrot.
 Mr. Albert Thorn, Washington, D. C., alligator.
 Mr. Henry C. Vaden, Washington, D. C., peafowl.
 Mr. J. S. Warmbath, Washington, D. C., screech owl.
 Mrs. Sarah Wilber, Keshena, Wis., American badger.
 Mr. J. M. Willson, Kissimmee, Fla., sand-hill crane.
 Mr. H. F. Winn, Chevy Chase, D. C., peafowl.
 Mr. H. E. Wright, Point of Rocks, Md., alligator.
 Unknown donor, fish crow.

Births.—The number of births exceeds that of any previous year in the history of the park. Mammals to the number of 76 were born, and 83 birds were hatched during the year, making a total of 159 additions to the collection in this manner. This record includes only such animals as are reared to a reasonable age, no account being made in these published statistics of such as live but a few days. The births include 2 European bears, 2 Rocky Mountain sheep, 1 eland, 4 Indian antelopes, 1 yak, 6 American bison, 2 llamas, 1 Columbian black-tailed deer, 2 Manchurian deer, 2 Kashmir deer, 2 American elk, 2 barasingha deer, 1 hog deer, 4 Japanese deer, 1

fallow deer, 6 white-tailed deer, 6 European red deer, 1 yellow-haired porcupine, 4 raccoons, 6 coypus, 3 rhesus monkeys, 1 dusky phalanger, 1 rufous-bellied wallaby, 1 great gray kangaroo, 4 red kangaroos, 8 opossums, and 2 brush-tailed rock kangaroos. The birds hatched are of the following species: Demoiselle crane, American coot, Florida cormorant, night heron, wild turkey, golden pheasant, peafowl, scaled quail, mute swan, Canada goose, mallard, black duck, and wood duck.

Exchanges.—There were received during the year 11 mammals and 70 birds in exchange for surplus animals born in the park. The mammals were 2 prong-horned antelopes, 2 Indian water buffaloes, 3 beavers, 3 spider monkeys, and 1 Burmese macaque. Many desirable water fowl, including coscoroba and black swans, Hutchins's geese, European widgeon, European teal, garganey teal, black-bellied tree ducks, and spur-winged geese, as well as numerous land birds needed for the collection, were received through exchange. Species new to the collection are the black-gorgeted laughing thrush, crimson tanager, blue tanager, thick-billed euphonia, diamond dove, bar-shouldered dove, short-keeled toucan, and a fine specimen of the remarkable Goliath heron from Africa.

Purchases.—Because of lack of funds only 38 mammals, birds, and reptiles were purchased during the year. A Malayan sun bear was obtained in San Francisco, a fallow deer buck was purchased for breeding, and a few small mammals were bought from time to time. Additions to the American waterfowl lake were 6 brants, 2 white-fronted geese, 10 black ducks, and an immature whistling swan. Two Florida sandhill cranes and a pair of bronze-wing pigeons, with some commoner hawks and owls, also were purchased.

Transfers.—Both the Biological Survey of the Department of Agriculture and the Bureau of Fisheries, Department of Commerce, contributed to the collection by the transfer of material collected by their agents in the field. From the Biological Survey was received an Apache grizzly bear and a mountain lion from New Mexico, a blue goose from Missouri, and two pigmy ground rattlers and a water snake from Florida. The Apache grizzly, new to the collection, is one of the recently defined species of the grizzly bear now nearing extinction. The specimen, a young male, was captured July 22, 1918, by T. J. McMullin and Bob Reid, 22 miles southeast of Taos, N. Mex., and was forwarded to the park by M. E. Musgrave, of the Biological Survey. It was apparently about 8 months old when received. A few turtles from Georgia were transferred from the Bureau of Fisheries.

Captured in the park.—A few birds captured in the park were added to the collection.

Deposited.—As usual, a number of desirable exhibition specimens were accepted on temporary deposit. These included for the year 7 parrots of various species, 2 boa constrictors, a lion, and a kinkajou. Eight alligators were carried over the winter for the Pan American Union.

REMOVALS.

Surplus mammals and birds to the number of 37 were exchanged to other zoological collections, as follows: One European brown bear, 1 hippopotamus, 2 red kangaroos, 1 yak, 3 Indian antelopes, 1 fallow deer, 2 hog deer, 1 Japanese deer, 4 barasingha deer, 4 European red deer, 6 gray squirrels, 2 domestic geese, and 9 peafowl. A number of specimens on deposit were returned to owners.

While the death rate for the year has been comparatively small, there have been as usual some serious losses, especially among animals long in the park and of advanced age. The male Celebesian dwarf buffalo, or anoa (*Anoa depressicornis*), which has been a feature of the antelope house for nearly 13 years, died on July 24, 1918. This animal came to the collection December 12, 1905, then fully adult, had been showing extreme age for the past two years, and his death was not unexpected. Two female Congo harnessed antelopes (*Tragelaphus gratus*) were lost. One was purchased as a fully grown animal October 31, 1907, and died May 10, 1919. The other, born in the park July 4, 1912, died February 27, 1919. An old female American bison, purchased May 6, 1907, died of septic metritis on April 20, 1919. A female guanaco, received from the zoological gardens in Buenos Aires, December 29, 1904, died on August 22, 1918, of acute congestion of the lungs, after 13 years and 8 months of life in the park. An alpaca, also from the Buenos Aires gardens, received March 14, 1908, died from old age and parasitic invasion, October 11, 1918. A wild cat (*Lynx ruffus*), received September 3, 1907, died January 22, 1919; and a Canada lynx, received September 25, 1907, died from septicemia September 25, 1918, exactly 11 years from the date of its arrival in the zoo. Other losses of importance among the mammals were a leopard, from pneumonia, November 18, 1918, and a young Brazilian tapir, born in the park February 22, 1918, which died under anesthetic during an operation for prolapse of the rectum on June 3, 1919.

The most serious loss by death among the birds was a female trumpeter swan, which died of septicemia May 14, 1919, just after it had been successfully mated, after two years of effort, with the male trumpeter lent to the park by Judge R. M. Barnes, of Lacon, Ill. The eggs in the ovary were enlarged to the size of cherries, and there is every reason to believe that but for the untimely loss of this

bird the swans would have been successfully bred. The African crowned hawk-eagle (*Spizaetus coronatus*) received from James Robert Spurgeon, United States Secretary of Legation, Monrovia, Liberia, June 24, 1901, died from avian tuberculosis, March 26, 1919, after 17 years and 9 months of life in the bird house. Two wandering tree ducks (*Dendrocygna arcuata*), received from Carl Hagenbeck, September 25, 1903, died, probably of old age, on September 30 and December 16, 1918, both having thus lived over 15 years in the gardens. A snowy egret (*Egretta candidissima*), received from Texas, June 15, 1907, died July 10, 1918, over 11 years from the date of its arrival.

Post-mortem examinations were made by the pathological division of the Bureau of Animal Industry. The following list shows the results of autopsies, the cases being arranged by groups:

CAUSES OF DEATH.

MAMMALS.

Marsupialia: Pneumonia, 2; tuberculosis, 1; peritonitis, 1; abscess in abdomen, 1.
 Carnivora: Pneumonia, 1; anemia, 1; septicemia, 1; abscess of jaw, 1.
 Rodentia: Pneumonia, 2; enteritis, 1; gastroenteritis, 1.
 Edentata: Adenomata, 1.
 Primates: Tuberculosis, 1; pleurisy, 1; enteritis, 1; gastroenteritis, 1; anemia, 1; sarcomatous tumor, 1; accident, 1; not determined, 1.
 Artiodactyla: Pneumonia, 3; tuberculosis, 3; congestion of lungs, 1; anemia, 1; septicemia, 2; septic metritis, 1; old age, 1; accident, 2.
 Perissodactyla: Anesthetic, during operation, 1.

BIRDS.

Ciconiiformes: Tuberculosis, 1; not determined, 1; no cause found, 1.
 Anseriformes: Tuberculosis, 3; enteritis, 4; ptomaine poisoning, 1; septicemia, 1; necrosis of caecum, 1; hemorrhage, 2; parasitism, 1; accident, 1; not determined, 2.
 Falconiformes: Tuberculosis, 1; aspergillosis, 1; not determined, 1.
 Galliformes: Aspergillosis, 1; enteritis, 2.
 Gruliformes: Tuberculosis, 1; enteritis, 1.
 Charadriiformes: Tuberculosis, 4; enteritis, 1; peritonitis, 1.
 Cuculiformes: Tuberculosis, 1; enteritis, 2; sarcomatosis, 1; no cause found, 1.
 Coraciiformes: Aspergillosis, 1.
 Passeriformes: Tuberculosis, 3; enteritis, 2; no cause found, 1.

Such animals, lost by death, as were of particular scientific importance, or needed for exhibition purposes, were transferred to the United States National Museum for preservation. These numbered 15 mammals and 25 birds.

ANIMALS IN THE COLLECTION JUNE 30, 1919.

MAMMALS.

MARSUPIALIA.

Virginia opossum (<i>Didelphis virginiana</i>)	9	Dusky phalanger (<i>Trichosurus fuliginosus</i>)	5
Tasmanian devil (<i>Sarcophilus harrisii</i>)	2	Brush-tailed rock kangaroo (<i>Petrogale penicillata</i>)	4
Phalanger (<i>Trichosurus vulpecula</i>)	3	Great gray kangaroo (<i>Macropus giganteus</i>)	3
		Red kangaroo (<i>Macropus rufus</i>)	9

Kangaroo Island kangaroo (<i>Macropus melanops</i>)	2
Wallaroo (<i>Macropus robustus</i>)	1
Black-tailed wallaby (<i>Macropus ualabatus</i>)	1
Rufous-bellied wallaby (<i>Macropus billardieri</i>)	4
Parma wallaby (<i>Macropus parma</i>)	1
Wombat (<i>Phascolomys mitchelli</i>)	1

CARNIVORA.

Kadiak bear (<i>Ursus middendorffi</i>)	1
Alaska Peninsula bear (<i>Ursus gyas</i>)	2
Yakutat bear (<i>Ursus dalli</i>)	1
Kidder's bear (<i>Ursus kidderi</i>)	2
European bear (<i>Ursus arctos</i>)	4
Grizzly bear (<i>Ursus horribilis</i>)	2
Apache grizzly (<i>Ursus apache</i>)	1
Himalayan bear (<i>Ursus thibetanus</i>)	1
Black bear (<i>Ursus americanus</i>)	3
Kenai black bear (<i>Ursus americanus perniger</i>)	1
Cinnamon bear (<i>Ursus americanus cinnamomum</i>)	2
Florida bear (<i>Ursus floridanus</i>)	2
Glacier bear (<i>Ursus emmonsii</i>)	1
Sun bear (<i>Helarctos malayanus</i>)	1
Sloth bear (<i>Melursus ursinus</i>)	1
Polar bear (<i>Thalarctos maritimus</i>)	2
Dingo (<i>Canis dingo</i>)	1
Eskimo dog (<i>Canis familiaris</i>)	2
Gray wolf (<i>Canis nubilus</i>)	10
Southern wolf (<i>Canis floridanus</i>)	1
Woodhouse's wolf (<i>Canis frustror</i>)	2
Coyote (<i>Canis latrans</i>)	3
Red fox (<i>Vulpes fulva</i>)	6
Gray fox (<i>Urocyon cinereoargenteus</i>)	5
Cacomistle (<i>Bassariscus astutus</i>)	2
Raccoon (<i>Procyon lotor</i>)	14
Gray coatimundi (<i>Nasua narica</i>)	1
Kinkajou (<i>Potos flavus</i>)	2
Ferret (<i>Mustela furo</i>)	1
Tayra (<i>Tayra barbara</i>)	1
Skunk (<i>Mephitis nigra</i>)	1
American badger (<i>Taxidea taxus</i>)	3
European badger (<i>Meles meles</i>)	2
Florida otter (<i>Lutra canadensis vaga</i>)	4
African civet (<i>Viverra civetta</i>)	1
Genet (<i>Genetta genetta</i>)	1
Spotted hyena (<i>Crocuta crocuta</i>)	1
Brown hyena (<i>Hyæna brunnea</i>)	1
Striped hyena (<i>Hyæna hyæna</i>)	2
African cheetah (<i>Acinonyx jubatus</i>)	2
Lion (<i>Felis leo</i>)	4
Bengal tiger (<i>Felis tigris</i>)	1
Manchurian tiger (<i>Felis tigris longipilis</i>)	2
Leopard (<i>Felis pardus</i>)	1
East African leopard (<i>Felis pardus suahelica</i>)	1
Jaguar (<i>Felis onca</i>)	1
Mexican puma (<i>Felis azteca</i>)	3
Mountain lion (<i>Felis hipposlestes</i>)	3
Canada lynx (<i>Lynx canadensis</i>)	2

Bay lynx (<i>Lynx rufus</i>)	5
California lynx (<i>Lynx californicus</i>)	1
Banded lynx (<i>Lynx fasciatus</i>)	1

PINNIPEDIA.

California sea lion (<i>Zalophus californianus</i>)	2
Harbor seal (<i>Phoca vitulina</i>)	1

ROBENTIA.

Woodchuck (<i>Marmota monax</i>)	3
Dusky marmot (<i>Marmota flaviventris obscura</i>)	1
Prairie dog (<i>Cynomys ludovicianus</i>)	12
Fox squirrel (<i>Sciurus niger</i>)	2
Albino squirrel (<i>Sciurus carolinensis</i>)	2
American beaver (<i>Castor canadensis</i>)	2
Crested porcupine (<i>Hystrix cristata</i>)	1
Yellow-haired porcupine (<i>Erethizon epixanthum</i>)	2
Coypu (<i>Myocastor coypus</i>)	7
Paca (<i>Cuniculus paca</i>)	3
Mexican agouti (<i>Dasyprocta mexicana</i>)	1
Azara's agouti (<i>Dasyprocta azarae</i>)	2
Crested agouti (<i>Dasyprocta cristata</i>)	2
Viscacha (<i>Lagostomus maximus</i>)	1
Patagonian cavy (<i>Dolichotis patagonica</i>)	1
Peruvian guinea pig (<i>Cavia tschudii pallidior</i>)	4
Guinea pig (<i>Cavia porcellus</i>)	23
Capybara (<i>Hydrochares hydrochares</i>)	1

LAGOMORPHA.

Domestic rabbit (<i>Oryctolagus cuniculus</i>)	28
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PRIMATES.

Gray spider monkey (<i>Ateles geoffroyi</i>)	2
White-throated capuchin (<i>Cebus capucinus</i>)	2
Margarita capuchin (<i>Cebus margaritæ</i>)	1
Chacma (<i>Papio porcarius</i>)	1
Hamadryas baboon (<i>Papio hamadryas</i>)	2
Mandrill (<i>Papio sphinx</i>)	1
Drill (<i>Papio leucophaeus</i>)	1
Moor macaque (<i>Cynopithecus maurus</i>)	1
Brown macaque (<i>Macaca speciosa</i>)	2
Japanese monkey (<i>Macaca fuscata</i>)	2
Burmese macaque (<i>Macaca andamanensis</i>)	1
Pig-tailed monkey (<i>Macaca nemestrina</i>)	1
Rhesus monkey (<i>Macaca rhesus</i>)	28
Bonnet monkey (<i>Macaca sinica</i>)	1
Javan macaque (<i>Macaca mordax</i>)	1
Philippine macaque (<i>Macaca syrichta</i>)	1
Sooty mangabey (<i>Cercocebus fuliginosus</i>)	2

Green guenon (<i>Lasiopyga callitrichus</i>)	1	Blesbok (<i>Damaliscus albifrons</i>)	1
Vervet guenon (<i>Lasiopyga pygerythra</i>)	1	White-tailed gnu (<i>Connochates gnu</i>)	1
Mona (<i>Lasiopyga mona</i>)	3	Defassa water-buck (<i>Kobus defassa</i>)	1
Roloway guenon (<i>Lasiopyga roloway</i>)	1	Indian antelope (<i>Antilope cervicapra</i>)	7
Patas monkey (<i>Erythrocebus patas</i>)	1	Nilgai (<i>Boselaphus tragocamelus</i>)	3
Chimpanzee (<i>Pan troglodytes</i>)	1	East African eland (<i>Taurotragus oryx livingstonii</i>)	3
ARTIODACTYLA.			
Wild boar (<i>Sus scrofa</i>)	1	Tahr (<i>Hemitragus jemlahicus</i>)	3
Wart-hog (<i>Phacochoerus aethiopicus</i>)	2	Aoudad (<i>Ammotragus lervia</i>)	1
Hippopotamns (<i>Hippopotamus amphibius</i>)	2	Rocky Mountain sheep (<i>Ovis canadensis</i>)	7
Bactrian camel (<i>Camelus bactrianus</i>)	2	Arizona mountain sheep (<i>Ovis canadensis gaillardi</i>)	1
Arabian camel (<i>Camelus dromedarius</i>)	2	Barbados sheep (<i>Ovis aries</i>)	5
Guanaco (<i>Lama huanachus</i>)	4	Zebu (<i>Bos indicus</i>)	1
Llama (<i>Lama glama</i>)	11	Yak (<i>Paephus grunniens</i>)	5
Alpaca (<i>Lama pacos</i>)	1	American blson (<i>Bison bison</i>)	23
Vicuña (<i>Lama vicugna</i>)	1	Indian buffalo (<i>Bubalus bubalis</i>)	2
Fallow deer (<i>Dama dama</i>)	3	PERISSODACTYLA.	
Axis deer (<i>Axis axis</i>)	6	Brazilian tapir (<i>Tapirus terrestris</i>)	2
Hog deer (<i>Hyelaphus porcinus</i>)	6	Mongolian horse (<i>Equus przewalskii</i>)	1
Sambar (<i>Rusa unicolor</i>)	2	Grant's zebra (<i>Equus burchelli granti</i>)	1
Luzon deer (<i>Rusa philippinus</i>)	1	Grevy's zebra (<i>Equus grevyi</i>)	2
Barasingha (<i>Rucervus duvaucelii</i>)	10	Zebra-horse hybrid (<i>Equus grevyi-caballus</i>)	1
Japanese deer (<i>Sika nippon</i>)	12	Zebra-ass hybrid (<i>Equus grevyi-asinus</i>)	1
Red deer (<i>Cervus elaphus</i>)	18	PROBOSCIDEA.	
Kashmir deer (<i>Cervus hanglu</i>)	6	Abyssinian elephant (<i>Loxodonta africana oryotis</i>)	1
Bedford deer (<i>Cervus xanthopygus</i>)	6	Sumatran elephant (<i>Elcphas sumatranus</i>)	2
American elk (<i>Cervus canadensis</i>)	7	BIRDS.	
Virginia deer (<i>Odocoileus virginianus</i>)	15	Black-crowned night heron (<i>Nycticorax nycticorax naevius</i>)	27
Mule deer (<i>Odocoileus hemionus</i>)	3	Boatbill (<i>Cochlearius cochlearius</i>)	2
Black-tailed deer (<i>Odocoileus columbianus</i>)	4	White stork (<i>Ciconia ciconia</i>)	3
Prong-horned antelope (<i>Antilocapra americana</i>)	2	Black stork (<i>Ciconia nigra</i>)	1
		Straw-necked ibis (<i>Carphibis spinicollis</i>)	1
		Sacred ibis (<i>Threskiornis aethiopicus</i>)	3
		White ibis (<i>Guara alba</i>)	10
		Scarlet ibis (<i>Guara rubra</i>)	2
		Roseate spoonbill (<i>Ajaia ajaja</i>)	2
		European flamingo (<i>Phaenicopterus roscus</i>)	1
		ANSERIFORMES.	
		Black-necked screamer (<i>Chauna torquata</i>)	1
		Mallard (<i>Anas platyrhynchos</i>)	17
		East Indian black duck (<i>Anas platyrhynchos</i> var.)	3
		Black duck (<i>Anas rubripes</i>)	21
		Gadwall (<i>Chauliasmus streperus</i>)	1
		European widgeon (<i>Mareca penelope</i>)	10
		Baldpate (<i>Mareca americana</i>)	7
		Green-winged teal (<i>Nettion carolinense</i>)	9

RATITAE.	
South African ostrich (<i>Struthio australis</i>)	
Somalliland ostrich (<i>Struthio molybdophanes</i>)	
Rhea (<i>Rhea americana</i>)	
Emu (<i>Dromiccius novae-hollandiae</i>)	

CICONIIFORMES.	
American white pelican (<i>Pelecanus erythrorhynchos</i>)	
European white pelican (<i>Pelecanus onocrotalus</i>)	
Roseate pelican (<i>Pelecanus roscus</i>)	
Australian pelican (<i>Pelecanus conspicillatus</i>)	
Brown pelican (<i>Pelecanus occidentalis</i>)	
Florida cormorant (<i>Phalacrocorax auritus floridanus</i>)	
Great white heron (<i>Ardea occidentalis</i>)	
Great blue heron (<i>Ardea herodias</i>)	
Goliath heron (<i>Ardea goliath</i>)	
Snowy egret (<i>Egretta candidissima</i>)	

European teal (<i>Nettion crecca</i>)-----	10
Blue-winged teal (<i>Querquedula discors</i>)-----	6
Garganey (<i>Querquedula querquedula</i>)--	1
Cinnamon teal (<i>Querquedula cyanoptera</i>)-----	1
Ruddy sheldrake (<i>Casarca ferruginea</i>)--	1
Pintail (<i>Dasila acuta</i>)-----	8
Wood duck (<i>Aix sponsa</i>)-----	14
Mandarin duck (<i>Dendronessa galericulata</i>)-----	21
Canvas-back (<i>Morila valisineria</i>)-----	2
Redhead (<i>Marila americana</i>)-----	7
Lesser scaup duck (<i>Marila affinis</i>)-----	6
Ring-necked duck (<i>Marila collaris</i>)-----	1
Rosy-billed pochard (<i>Metopiana peposaca</i>)-----	1
Snow goose (<i>Chen hyperboreus</i>)-----	3
Greater snow goose (<i>Chen hyperboreus nivalis</i>)-----	2
Blue goose (<i>Chen caerulescens</i>)-----	3
White-fronted goose (<i>Anser albifrons</i>)--	6
American white-fronted goose (<i>Anser albifrons gambeli</i>)-----	3
Bar-headed goose (<i>Eulabeia indicus</i>)--	1
Canada goose (<i>Branta canadensis</i>)-----	26
Hutchins's goose (<i>Branta canadensis hutchinsii</i>)-----	5
Cackling goose (<i>Branta canadensis minima</i>)-----	2
Brant (<i>Branta bernicla glaucogastra</i>)--	1
Barnacle goose (<i>Branta leucopsis</i>)-----	8
Spur-winged goose (<i>Plectropterus gambensis</i>)-----	3
Black-bellied tree duck (<i>Dendrocygna autumnalis</i>)-----	6
White-faced tree duck (<i>Dendrocygna viduata</i>)-----	3
Coscoroba (<i>Coscoroba candida</i>)-----	1
Mute swan (<i>Cygnus gibbus</i>)-----	6
Whistling swan (<i>Olor columbianus</i>)--	2
Trumpeter swan (<i>Olor buccinator</i>)-----	1
Black swan (<i>Chenopsis atrata</i>)-----	3

FALCONIFORMES.

South American condor (<i>Vultur gryphus</i>)-----	1
California condor (<i>Gymnogyps californianus</i>)-----	3
Turkey vulture (<i>Cathartes aura</i>)-----	4
Black vulture (<i>Coragyps urubu</i>)-----	2
King vulture (<i>Sarcorampus papa</i>)-----	2
Secretary bird (<i>Sagittarius serpentarius</i>)-----	1
Griffon vulture (<i>Gyps fulvus</i>)-----	2
Cinereous vulture (<i>Acgypius monachus</i>)-----	2
Caracara (<i>Polyborus cheriway</i>)-----	3
Wedge-tailed eagle (<i>Uroaetus audax</i>)--	2
Golden eagle (<i>Aquila chrysaetos</i>)-----	2
Bald eagle (<i>Haliaeetus leucocephalus</i>)--	12
Alaskan bald eagle (<i>Haliaeetus leucocephalus alascanus</i>)-----	1
Sparrow hawk (<i>Falco sparverius</i>)-----	1
Red-tailed hawk (<i>Buteo borealis</i>)-----	2
Swainson's hawk (<i>Buteo swainsoni</i>)-----	1

GALLIFORMES.

Mexican curassow (<i>Crao globicera</i>)-----	2
Daubenton's curassow (<i>Crao daubentoni</i>)-----	1
Chicken-guinea hybrid (<i>Gallus</i> × <i>Nu-mida</i>)-----	1
Wild turkey (<i>Meleagris gallopavo silvestris</i>)-----	2
Peafowl (<i>Pavo cristatus</i>)-----	43
Peacock pheasant (<i>Polyplectron bicalcaratum</i>)-----	1
Silver pheasant (<i>Gennæus nycthemerus</i>)-----	1
Lady Amherst's pheasant (<i>Chrysolophus amherstiae</i>)-----	1
Golden pheasant (<i>Chrysolophus pictus</i>)--	9
Bobwhite (<i>Colinus virginianus</i>)-----	2
Scaled quail (<i>Callipepla squamata</i>)-----	4
Gambel's quail (<i>Lophortyx gambelii</i>)--	2
Valley quail (<i>Lophortyx californica vallicola</i>)-----	8

GRUIFORMES.

American coot (<i>Fulica americana</i>)-----	9
South Island weka rail (<i>Ocydromus australis</i>)-----	3
Short-winged weka (<i>Ocydromus brachypterus</i>)-----	2
Earl's weka (<i>Ocydromus earli</i>)-----	1
Whooping crane (<i>Grus americana</i>)-----	1
Sandhill crane (<i>Grus mexicana</i>)-----	5
White-necked crane (<i>Grus leucauchen</i>)--	1
Indian white crane (<i>Grus leucogeranus</i>)-----	1
Lilford's crane (<i>Grus lilfordi</i>)-----	2
Australian crane (<i>Grus rubicunda</i>)-----	1
Demolselle crane (<i>Anthropoides virgo</i>)--	8
Crowned crane (<i>Balearia pavonina</i>)-----	2
Carliama (<i>Carliama cristata</i>)-----	1

CHARADRIIFORMES.

Great black-backed gull (<i>Larus marinus</i>)-----	1
Herring gull (<i>Larus argentatus</i>)-----	1
Laughing gull (<i>Larus atricilla</i>)-----	2
Australian crested pigeon (<i>Ocyphaps lophotes</i>)-----	3
Bronze-wing pigeon (<i>Phaps chalcoptera</i>)-----	1
Wonga-wonga pigeon (<i>Leucosarcia picta</i>)-----	9
Red-billed pigeon (<i>Chlorænas flavirostris</i>)-----	1
White-winged dove (<i>Melopelia asiatica</i>)-----	1
Mourning dove (<i>Zenaidura macroura</i>)--	1
Diamond dove (<i>Geopelia cuneata</i>)-----	2
Zebra dove (<i>Geopelia striata</i>)-----	10
Bar-shouldered dove (<i>Geopelia humeralis</i>)-----	2
Inca dove (<i>Scardafella inca</i>)-----	3
Blue-headed quail-dove (<i>Starnænas cyanocephala</i>)-----	1
Ringed turtle-dove (<i>Streptopelia risoria</i>)-----	15

PSITTACIFORMES.

Grass paroquet (<i>Melopsittacus undulatus</i>)	2
Black-tailed paroquet (<i>Polytelis melanura</i>)	1
Lesser vasa parrot (<i>Coracopsis nigra</i>)	1
Gray parrot (<i>Psittacus erithacus</i>)	2
Haitian paroquet (<i>Aratinga chloroptera</i>)	1
Blue-winged parrotlet (<i>Psittacula passerina</i>)	1
Cuban parrot (<i>Amazona leucacephala</i>)	6
Isle of Pines parrot (<i>Amazona leucocephala palmarum</i>)	1
Yellow-shouldered parrot (<i>Amazona barbadensis</i>)	1
Festive parrot (<i>Amazona festiva</i>)	1
White-fronted parrot (<i>Amazona albifrons</i>)	1
Orange-winged parrot (<i>Amazona amazonica</i>)	1
Santo Domingo parrot (<i>Amazona ventralis</i>)	2
Yellow-headed parrot (<i>Amazona ochracephala</i>)	8
Yellow-naped parrot (<i>Amazona auro-palliata</i>)	2
Double yellow-head parrot (<i>Amazona oratrix</i>)	10
Yellow-cheeked parrot (<i>Amazona autumnalis</i>)	1
Thick-billed parrot (<i>Rhynchopsitta pachyrhyncha</i>)	2
Red-and-blue macaw (<i>Ara chloroptera</i>)	2
Red-and-blue-and-yellow macaw (<i>Ara macao</i>)	7
Blue-and-yellow macaw (<i>Ara ararauna</i>)	1
Sulphur-crested cockatoo (<i>Cacatoes galerita</i>)	2
Great red-crested cockatoo (<i>Cacatoes moluccensis</i>)	1
White cockatoo (<i>Cacatoes alba</i>)	2
Leadbeater's cockatoo (<i>Cacatoes leadbeateri</i>)	1
Bare-eyed cockatoo (<i>Cacatoes gymnopsis</i>)	3
Roseate cockatoo (<i>Cacatoes roseicapilla</i>)	11
Kea (<i>Nestor notabilis</i>)	5

CORACIIFORMES.

Glant kingfisher (<i>Dacelo gigas</i>)	2
Short-keeled toucan (<i>Ramphastos piscivorus brevicarinatus</i>)	1

Concave-casqued hornbill (<i>Dichaceros bicornis</i>)	1
Barred owl (<i>Strix varia</i>)	7
Screech owl (<i>Otus asio</i>)	6
Great horned owl (<i>Bubo virginianus</i>)	4
Western horned owl (<i>Bubo virginianus pallescens</i>)	1
American barn owl (<i>Tyto perlatia pratincola</i>)	2

PASSERIFORMES.

Red-billed hill-tilt (<i>Liothrix luteus</i>)	3
Black-gorgeted laughing-thrush (<i>Garulax pectoralis</i>)	4
Hermit thrush (<i>Hylocichla guttata pallasi</i>)	1
Australian gray jumper (<i>Struthidea cinerea</i>)	1
Green jay (<i>Xanthoura luzuosa</i>)	1
Australian crow (<i>Corvus coronoides</i>)	1
Fish crow (<i>Corvus assifragus</i>)	1
European raven (<i>Corvus corax</i>)	1
Napoleon weaver (<i>Pyromelana afra</i>)	2
Madagascar weaver (<i>Foudia madagascariensis</i>)	4
Paradise widow bird (<i>Steganura paradisica</i>)	1
Cut-throat finch (<i>Amadina fasciata</i>)	1
Zebra finch (<i>Teniopygia coronotis</i>)	6
Black-faced Gouldian finch (<i>Poephila gouldiae</i>)	5
Red-faced Gouldian finch (<i>Poephila mirabilis</i>)	1
Strawberry finch (<i>Amandava amandava</i>)	8
Black-headed finch (<i>Munia atricapilla</i>)	1
Nutmeg finch (<i>Munia punctulata</i>)	10
Java finch (<i>Munia oryzivora</i>)	10
White Java finch (<i>Munia oryzivora</i>)	1
Vera Cruz red-wing (<i>Agelaius phoeniceus richmondi</i>)	2
Crimson tanager (<i>Ramphocelus dimidiatus</i>)	3
Blue tanager (<i>Thraupis cana</i>)	3
Thick-billed euphonia (<i>Tanagra crassirostris</i>)	3
Song sparrow (<i>Melospiza melodia</i>)	1
Slate-colored junco (<i>Junco hyemalis</i>)	4
White-throated sparrow (<i>Zonotrichia albicollis</i>)	3
Saffron finch (<i>Sicalis flaveola</i>)	3
Canary (<i>Scrinus canarius</i>)	4
Green singing finch (<i>Serinus icterus</i>)	1
European chaffinch (<i>Fringilla caelebs</i>)	1
Red-crested cardinal (<i>Paroaria cucullata</i>)	1
Cardinal (<i>Cardinalis cardinalis</i>)	3

REPTILES.

Alligator (<i>Alligator mississippiensis</i>)	28	Blue-tongued lizard (<i>Tiliqua scincoides</i>)	1
Mona Island iguana (<i>Cyclura stejnegeri</i>)	1	Chameleon (<i>Anolis carolinensis</i>)	1
Gila monster (<i>Heloderma suspectum</i>)	7	Horned toad (<i>Phrynosoma cornutum</i>)	2

Rock python (<i>Python molurus</i>)-----	3	Ground rattler (<i>Sistrurus miliarius</i>)--	1
Diamond python (<i>Python spilotes</i>)-----	1	Duncan Island tortoise (<i>Testudo ehip-</i>	
Anaconda (<i>Eunectes murinus</i>)-----	2	pium)-----	1
Boa constrictor (<i>Constrictor constrictor</i>)-----	6	Albemarle Island tortoise (<i>Testudo</i>	
Rainbow snake (<i>Abaster erythrogram-</i>		vicina)-----	1
mus)-----	1	Gopher tortoise (<i>Gopherus polyphemus</i>)-----	2
Blacksnake (<i>Coluber constrictor</i>)-----	1	Snapping turtle (<i>Chelydra serpentina</i>)--	2
Chicken snake (<i>Elaphe quadrivittata</i>)--	1	Cooter (<i>Pseudemys scripta</i>)-----	1
Water snake (<i>Natrix sipedon</i>)-----	5	Florida terrapin (<i>Pseudemys floridana</i>)-----	1
Garter snake (<i>Thamnophis sirtalis</i>)-----	1		
Moccasin (<i>Agkistrodon piscivorus</i>)-----	1		

STATEMENT OF THE COLLECTION.

ACCESSIONS DURING THE YEAR.

Presented:		Captured in National Zoological	
Mammals -----	19	Park:	
Birds -----	25	Birds-----	10
Reptiles -----	30	Deposited:	
	74	Mammals -----	2
Born and hatched in the National		Birds -----	7
Zoological Park:		Reptiles -----	10
Mammals -----	76		19
Birds -----	83	Total accessions-----	390
	159		
Received in exchange:		SUMMARY.	
Mammals -----	11	Animals on hand July 1, 1918-----	1,247
Birds -----	70	Accessions during the year-----	390
	81		1,637
Purchased:		Deduct loss (by exchange, death, and	
Mammals -----	9	return of animals on deposit)---	301
Birds -----	27		
Reptiles -----	2	Animals on hand June 30, 1919--	1,336
	38		
Transferred from other Govern-			
ment departments:			
Mammals -----	2		
Birds -----	1		
Reptiles -----	6		
	9		

Class.	Species.	Individuals.
Mammals.....	156	528
Birds.....	190	737
Reptiles.....	23	71
Total.....	369	1,336

VISITORS.

The record for number of visitors during a single fiscal year has again been exceeded. The number of people admitted to the park, as determined by count and estimate, was 1,964,715, a daily average of 5,383. The greatest number in any one month was 355,651, in April, 1919, an average per day of 11,855. On March 23, 1919, there were 70,000 visitors; on Sunday, April 6, 1919, 85,000; and on Easter Monday, April 21, 1919, 55,359 (actual count at gates).

The attendance by months was as follows: In 1918: July, 160,600; August, 116,200; September, 154,600; October, 114,500; November, 91,400; December, 93,424. In 1919: January, 101,625; February, 115,150; March, 242,650; April, 355,651; May, 220,700; June, 198,215.

The record for attendance for the year ending June 30, 1918, which exceeded the previous record year (1916) by 436,117, was beaten by 371,488. Following are the attendance records for the past eight years:

1912-----	542, 738	1916-----	1, 157, 110
1913-----	633, 526	1917-----	1, 106, 800
1914-----	733, 277	1918-----	1, 593, 227
1915-----	794, 530	1919-----	1, 964, 715

The park continues in popularity as a means of instruction to schools and classes, as well as a resort for out-of-doors gatherings for large picnic parties, where the usual woodland surroundings and pleasures may be supplemented by visits to the zoological collections. Ninety-eight such schools and classes visited the park in 1919, with a total of 6,169 individuals. These came not only from the District of Columbia, Maryland, and Virginia, but from the more distant States of Pennsylvania, New Jersey, Massachusetts, and Ohio. The American Society of Mammalogists held an informal meeting with luncheon at the park on April 4, 1919, with 75 members in attendance.

IMPROVEMENTS.

Exterior cages for leopards, jaguars, and hyenas, on the east side of the north wing of the lion house, were nearly completed before the close of the year. The cages are seven in number, 24 feet deep, and 74 feet long over all. The cost, including material and the labor of regular employees, was \$3,410. This long-desired improvement adds greatly to the appearance of the building and to the comfort of the animals.

A perforated radial brick chimney 80 feet in height above the concrete foundation and 42 inches interior diameter at the top was built at the central heating plant to replace the old and worn-out metal stack. The concrete base was constructed by the park workmen and the chimney by contract, at a total cost of \$2,647.

A public toilet 13 by 28 feet 8 inches was constructed near the Connecticut Avenue entrance. Some of the materials for this work were purchased from the 1918 appropriation, and the labor was all by regular employees of the park. The cost of this structure, including labor, was \$1,200.

The smaller elephant house, roofs of the larger elephant house and restaurant building, outdoor lion and tiger cages, outdoor cages on east and west sides of monkey house, and other fences and inclosures

were painted, at a total cost of \$1,586. The materials, amounting to \$475, were furnished by the park. The contracts for labor totaled \$1,111.

The creek-side drive from Klinge Ford to the crossroads and the main road from the concrete bridge to the concourse were broken up and rebuilt, the creek-side drive from crossroads to the stone bridge was resurfaced, and roads in other parts of the park were repaired and resurfaced where necessary. The cost of materials for road work was \$1,295, and the labor, including regular park employees and temporary men, amounted to \$1,475.50.

Other minor improvements and repairs completed during the year include a new fence around the nursery and gardens, concrete steps to replace old stone steps leading from wolf dens up to bear yard steps, cement stairway from Cathedral Avenue leading down into park under the Calvert Street Bridge, repair of walks leading in from Adams Mill gate, repair of bridle paths, drainage for zebra house and yards, paving in zebra yards, a new policeman's box at Klinge gate. The old wooden ties of the fence of the large elephant yard were replaced by an iron fence to match the permanent sections already constructed. A number of large wire receptacles for rubbish and 100 new park benches were provided.

IMPORTANT NEEDS.

Alteration of the western boundary.—By an act approved June 23, 1913, Congress appropriated \$107,200 for the purchase of certain lots and parcels of land between the western boundary of the National Zoological Park and Connecticut Avenue, from Cathedral Avenue to Klinge Road, this land, together with the included highways, to become a part of the park. The appropriation was not a continuing one and lapsed at the end of the following fiscal year, before proceedings for the purchase of the land were completed. Items for the reappropriation of this sum and for the additional amount necessary to meet the figures fixed by the court in proceedings of condemnation were submitted to Congress in the following years, but were not favorably considered. Following a suggestion made by the chairman of the Appropriations Committee at the hearing on the bill for 1919, the item for the purchase of this land was revised in the estimate for 1920 to include only a portion of the property originally appropriated for in 1913. The land asked for in the estimates submitted for 1920 and, failing approval, again included in estimates for 1921, includes 250 feet each side of Jewett Street, fronting on Connecticut Avenue, and all of the land inside the unnamed road between Connecticut Avenue and the park, excepting one lot. This, with all of Jewett Street, and the included portion of the unnamed

street, would satisfy all the important needs of the park and give a frontage of over 600 feet on Connecticut Avenue. One of the principal entrances to the park will always be from Connecticut Avenue and the importance of a frontage on that thoroughfare at and bordering the gate can not be overestimated. The necessary land can now be purchased for about \$80,000, and should be acquired before it is too late.

Alteration of the southeastern boundary.—The question of the purchase of a narrow strip of land between the park and Adams Mill Road, from Clydesdale Place to Ontario Road, still in private ownership, is now brought forcibly to our attention because of improvements being made at that point by the District government. As this newly developed section of Adams Mill Road will doubtless become one of the most used highways connecting the park systems, and as the privately owned strip is within a few feet of the Adams Mill Road entrance to the park, the need for public ownership can not be questioned. The amount required is comparatively small and the purchase of the land should not long be delayed, as the bordering road is soon to be opened, and the ownership of the narrow strip by the Government and its incorporation within the park is of very great interest to the public.

Restaurant.—One of the most urgent needs of the park is a suitable restaurant. The present refreshment stand is entirely inadequate and is in a very bad state of repair. On any of the days of reasonably large attendance the public can be only poorly served and the facilities of the stand are overtaxed. It is believed that a suitable building, on the present site, 50 by 100 feet in size, and of two floors, one opening onto the lower slope to the west, would meet the requirements. Such a building, properly equipped and under first-class management, would be greatly appreciated by the constantly increasing number of visitors to the park.

Grading banks and filling ravines.—The work of further cutting away the irregular hill in the center of the western part of the park and the filling in of a near-by ravine, commenced three years ago but discontinued for lack of funds, should be completed as soon as practicable. Level spaces for yards and inclosures are very much needed, and the work as left makes an unsightly and unfinished looking place in one of the most conspicuous points in the park, bordering on the main road. Completion of the work will level nearly 70,000 square feet of ground which is now of little use, make available a further 25,000 square feet of ground at the ravine, and eliminate a dangerous curve in the automobile road.

Purchase of animals.—A sufficient sum for the purchase and transportation of animals has never been available and is greatly to be

desired, so that the park may take advantage from time to time of opportunities to obtain rare and conspicuous animals not before exhibited.

Aviary building.—The need of a new house for the exhibition of birds continues to become more urgent from year to year. The old building is rapidly becoming unfit for use and the public aisles are entirely too narrow for the crowds of people who now visit the park.

The cost of maintenance during the past year has reached a sum greater than ever before. Owing to the increased cost of almost every item, the amount required for food for animals was \$33,149, and repairs and new improvements are similarly expensive. It is urgent, therefore, if there is to be any expenditure for improvements or for necessary repairs that an increase be made in the general appropriation for the expenses of the park.

Respectfully submitted.

N. HOLLISTER, *Superintendent.*

Dr. CHARLES D. WALCOTT,

Secretary Smithsonian Institution,

Washington, D. C.

APPENDIX 5.

REPORT ON THE ASTROPHYSICAL OBSERVATORY.

SIR: The Astrophysical Observatory was conducted under the following passage of the sundry civil act approved July 1, 1918:

Astrophysical Observatory: For maintenance of Astrophysical Observatory, under the direction of the Smithsonian Institution, including assistants, purchase of necessary books and periodicals, apparatus, making necessary observations in high altitudes, repairs and alterations of buildings, and miscellaneous expenses, \$13,000.

The observatory occupies a number of frame structures within an inclosure of about 16,000 square feet south of the Smithsonian administration building at Washington, and also a cement observing station and frame cottage for observers on a plot of 10,000 square feet leased from the Carnegie Solar Observatory, on Mount Wilson, Calif.

The present value of the buildings and equipment is estimated at \$50,000. This estimate contemplates the cost required to replace the outfit for the purpose of the investigations.

WORK OF THE YEAR.

At Washington.—As usual, the computation of the results of solar constant observations made at Mount Wilson, Calif., has gone on steadily at Washington, except as interrupted by the furlough of the computer, Miss Graves, for work in France, as mentioned under the subheading "Personnel." After the services of other computers had been obtained the work went on rapidly and is now nearly up to date.

The preparation of Volume IV of the *Annals of the Astrophysical Observatory*, including results of measurements from the year 1913, has been occupying the attention of the director to a very great extent since February.

In consideration of the fact that the total eclipse of the sun of May 29, 1919, was visible in La Paz, Bolivia, which is not very far from the Smithsonian solar-constant observing station in Calama, Chile, and in further consideration of the fact that the Argentine Government is using the daily telegraphic reports of the solar observations at Calama for forecasting purposes; and, further, that certain conditions had arisen at Calama which would seem to require

the personal investigation of the writer, it appeared necessary to make an expedition to South America to attend to these several matters. The preparation for the eclipse work occupied some time of the director and of the instrument maker.

Several investigations relating to the war, a brief note of which was mentioned in last year's report, were continued during the fiscal year.

The painstaking and valuable work which Mr. Fowle has been doing on the revision of the Smithsonian Physical Tables should receive some notice, although this work is being done by him outside of his regular hours of service for the observatory. This book has passed through a number of editions under his editorship and has attained an enviable reputation in this country and abroad for the accuracy and fullness of its contents. The new edition, which is now in press, has received unusual attention on his part, and very valuable cooperation from the various scientific departments of the Government and of outside individuals in colleges and industrial corporations and elsewhere, and will be a great advance over any of the former editions.

In connection with work of the Observatory, we have long wished to determine the solar constant of radiation by a method which does not involve the assumption that the transparency of the atmosphere is constant over the two or three hours required for the determination of it by the usual spectrobolometric method. We hoped that, seeing that the sky is brighter when the transparency is less, an observation by the pyranometer, or some other more suitable instrument, of the brightness of the sky in the neighborhood of the sun, combined with the usual measurements of the pyrheliometer and perhaps of the spectrobolometer, but only at one period of time, might be sufficient to determine the solar constant by a satisfactory empirical process based upon spectrobolometric investigations of former years. In the hope of getting an instrument more satisfactory than the pyranometer for this special work, a new design comprising essentially two disks, one of which is shined upon through a graduated aperture by the sun and the other of which is exposed to the small region of sky desired and both connected by thermoelectric junction so as to enable equality of temperature of the two disks to be adjusted, was devised and partly constructed at Washington. It was sent in a letter to Calama, Chile, and was finished by the director during his visit in Chile and is now in satisfactory operation, although it has not yet supplanted the pyranometer for the purpose in question.

Another problem which requires a new kind of apparatus is the measurement of nocturnal radiation such as the earth sends out to space. This investigation is exceptionally difficult, for it involves a

range of wave length from 5 microns to 50 microns. There is no surface either of blackened metal or other substance which is fully absorbing to the rays throughout this whole extent, and furthermore there is no optical medium known by means of which the properties of the rays beyond about 17 microns, where rock salt ceases to be transparent, may be investigated. For the purpose of determining nocturnal radiation it seems absolutely indispensable that there should be devised an instrument based upon the principle of the perfect radiator or "absolutely black body." This is a very difficult thing because not only does the instrument have to be exposed to the full hemisphere of 180° of solid angle, but also the radiation to be observed is small in amount, little more than the tenth part of the radiation of the sun. Seeing that the "black body," so called, requires to be a hollow chamber, large with respect to the aperture through which the rays enter, the rise of temperature of its walls which must be measured is extremely small. After much consultation, Mr. Aldrich and the director decided upon a design of a new instrument for this purpose. This was constructed in the spring of 1919, and is now in use on Mount Wilson. Whether it will prove to be satisfactory or not remains a question.

In order to investigate the rays beyond the wave length where rock salt becomes opaque a great many measurements have been made by Mr. Aldrich, as mentioned in the last report, to attempt to find some substance transmissible to such rays. The best substance found appeared to be potassium iodide. It usually occurs as crystals no larger than a buckshot. Accordingly, in order to make any satisfactory progress it was necessary to procure larger crystals, preferably large enough to make a prism of five or more centimeters on an edge, but at least so large that such a prism could be built up by cementing parts of it together. Experiments had been made at the General Electric Co. for producing large crystals needed in war operations, and they very kindly undertook to try to grow potassium iodide crystals also. A number of crystals, very satisfactorily clear, have been produced by them as large as 2 centimeters on each edge, and from a sufficient number of these the prism required for going on with this long wave length work may probably be formed.

Mr. Aldrich spent a long time on the development and testing of an apparatus for determining the constant of the fourth power radiation formula ordinarily called σ . This is a very difficult research. The quantity is already certainly known within 5 per cent and many physicists would believe even closer than this. Many researches have been made upon it and in order to do a piece of work worth while it is necessary to show that it is certainly accurate to 1 per cent. After many experiments it was found that this

degree of certainty could not be secured with the apparatus which Mr. Aldrich and the director had designed and which Mr. Kramer, the instrument maker, had constructed, and so the work was given over for a time.

At Mount Wilson.—Mr. Aldrich continued the observations of the solar constant of radiation until the middle of October, 1918, and returned to continue them early in June, 1919. In September of 1918 he made a very interesting observation in cooperation with the Army Balloon School at Arcadia at the foot of Mount Wilson. It consisted in arranging a pyranometer to be hung below the basket of a captive balloon, which could be raised above the level of the great horizontal layer of fog which often covers the San Gabriel and other valleys in the neighborhood of Los Angeles in a sheet many miles in extent. On this occasion the layer of fog extended from 1,000 feet of altitude to 2,500 feet. The balloon was raised to about 200 feet above the layer. An officer of the balloon school exposed the apparatus under the balloon to the radiation from the sheet of fog, while Mr. Aldrich, on the ground, observed the deflections of the galvanometer. The galvanometer was connected to the pyranometer by a pair of wires about a half mile long. Simultaneously observations were made on Mount Wilson with the pyrliometer to determine the exact character of the day, and on other days of similar character Mr. Aldrich exposed the pyranometer to the radiation of the sun and sky combined. Thus knowing the radiation reflected from the sheet of fog, and knowing the radiation on a similar day coming down from the sun and sky, he was able to determine the reflecting power of a great layer of fog. This observation is very useful for the study of the relations of the temperature of the earth to radiation. The result of the experiments, which were continued for several hours without interruption, was very satisfactory. The final value for the reflecting power of a great horizontal sheet of fog was 78 per cent.

The weather on Mount Wilson, in the autumn of 1918, was uncommonly poor for the solar constant work, as rain fell frequently and a great many clouds came up. Altogether it was the most unfavorable weather which has been experienced in any observing season there since it was occupied for solar constant purposes.

SOUTH AMERICAN EXPEDITION.

Several considerations led to the decision to make a small expedition to South America in the spring of 1919. The Institution had equipped an observatory at Calama, Chile, to measure the solar constant of radiation. The Argentine meteorological service, through its chief forecaster, Mr. Clayton, had been determining the effects of the variation of the sun on the temperature and other weather condi-

tions of the earth, and had been so much impressed by the value of the solar variation observations for forecasting purposes that they had arranged to receive daily telegraphic reports of the values obtained at Calama, Chile. The director of the observatory at Calama, Mr. Moore, had conceived a feeling that the sky conditions were not as favorable as perhaps might be secured in other parts of South America or elsewhere and feared that it was unwise for the Institution to continue to conduct the operations there. On all of these accounts it seemed necessary for Dr. Abbot to go to South America and deal with these several matters.

In accordance with the sundry civil act, which failed of passage on March 4, 1919, but was approved July 19, 1919, the following authorization was secured:

The unexpended balance of the appropriation "For observation of the total eclipse of the sun of June 8, 1918, and so forth," is reappropriated and made available for observation of the total eclipse of the sun of May 28, 1919, visible in Bolivia.

The two 11-foot focus 3-inch cameras employed by the Smithsonian observers at Wadesboro, N. C., in 1900, and again by Mr. Aldrich in 1918, were equipped with a collapsible tube and other mechanism, so that they could be speedily arranged with equatorial clock-driven motion to photograph an eclipse in South America. Mr. Moore, at Calama, was instructed to arrange to join Dr. Abbot with the pyranometer employed there, so as to observe the degree of darkening of the sky and sun as the eclipse progressed. Arrived at Calama, the apparatus was repacked for use in the field, and Messrs. Moore and Abbot proceeded to La Paz, Bolivia, where, owing to the kindness shown by Mr. Babbage, of the railroad, arrangements were made to observe close to the railroad station at El Alto, situated about 1,500 feet above La Paz, at an altitude of about 14,000 feet above sea level. The day of the eclipse, May 29, proved very favorable. The sky was entirely cloudless in the neighborhood of the sun for several hours. Mr. Moore had observed during the day before and during the night, and continued his observations each minute throughout the totality and the succeeding partial phase up until about two hours after sunrise. Dr. Abbot had set up and adjusted the photographic telescope with Mr. Moore's aid, and except for one defect it operated perfectly. This was that since the eclipse took place so very early in the morning, only 20 minutes after sunrise, the rate of motion of the sun above the horizon was not uniform with that which would occur in the middle of the day, owing to refraction. The apparatus had only been set up the day before, so that there was not time to work out this matter to know exactly how to rate the clock at the moment of eclipse. Preliminary observations of May 28 had indicated that the clockwork ran a little too slow. During the day it was speeded up

a little, but on the day of the eclipse it proved to be a trifle too fast, so that the moon appears to be elliptical rather than perfectly round, as it should have been, except for the slight motion of the moon relative to the sun during the eclipse. However, this defect is not very noticeable, and excellent photographs were obtained with both lenses, but particularly with the one which was exposed 1 minute and 30 seconds rather than the other, which was exposed $2\frac{1}{4}$ minutes.

The phenomenon was uncommonly grand, far more so than appears in the photograph. The sun had risen over a snow-capped mountain, about 20,000 feet high. It rose over half eclipsed, with the crescent horns pointing upward from the horizon equally. In 20 minutes totality occurred, and there shot out over 20 fine sharp coronal rays, greatest elongated along the equatorial zone, but also visible to great distances from the poles. At the lower limb there was a very large flaming red prominence, which at that time rose to perhaps a quarter of the solar radius, and had a very long side extension, after the manner of a hook. The same prominence was observed by spectroscopic methods in the United States, at the great observatories, and was one of the finest prominences ever photographed. It is very interesting and fortunate that the early history of this prominence was enriched by the photograph made at La Paz so very early in the morning.

Taking the whole phenomenon together, the snow-covered mountain, the brilliant sky at that great altitude of 14,000 feet, the very numerous and long coronal streamers, and the enormous crimson prominence casting its glow over all, the spectacle was truly glorious, and by far the most impressive of any of the eclipses which have been seen by the writer. It was reported that the Bolivian natives lighted many fires and supplicated the sun to return, after old Inca traditions.

Visit to Argentina.—Immediately after the eclipse Messrs. Moore and Abbot proceeded to La Quiaca in Argentina for the purpose of having a conference there with the director and forecaster of the Argentine meteorological service. Mr. Clayton, the official forecaster, submitted for their inspection results he had obtained during several years in the comparison of the weather of Argentina with the variations of solar radiation reported by the Smithsonian observers at Mount Wilson, Calif., and Calama, Chile, and the results obtained by using the measurements of Calama for the forecasting of the weather in Argentina.

Mr. Clayton says:

For nearly a year numerical and graphical analyses have been made of the solar variations and of the variations of temperature at 20 selected stations well distributed over Argentina, Chile, and Brazil. These analyses show that each variation in solar radiation has been followed by similar variations of tem-

perature in South America, with a few exceptions that may easily have resulted from errors in the measurements of solar radiation. At Buenos Aires the ratio of temperature change to solar change at the time of greatest solar activity was found from the averages of several years to be 1.4 C. for each change of 1 per cent in solar radiation. Since the extreme solar values range about 6 per cent on either side of the mean, there might result departures from the normal at Buenos Aires from this cause of about 8.5 C. The extreme departure from the normal observed at Buenos Aires during the last 13 years has been 11.5 C. The results of these researches have led me to believe that the existing abnormal changes which we call weather have their origin chiefly, if not entirely, in the variation of solar radiation.

Naturally, these results, which are supported by an enormous amount of careful and conscientious computation on the part of the forecasting division of the Argentine meteorological service, are of extreme interest. They point to the great desirability of equipping in different cloudless regions of the world several observatories designed for the measurement of the solar constant of radiation. The chief of the Argentine weather service, Mr. Wiggin, desires very much to take over the South American station of the Smithsonian Institution, to be maintained by the Argentine meteorological service. Tentative arrangements were entered into between Dr. Abbot and Mr. Wiggin for this purpose, which, however, require the further approval of the Argentine Government to become effective. If suitable arrangements for the transfer can be made, it is hoped to employ the funds thereby set loose for the establishment by the Smithsonian Institution of a solar station in Egypt.

From Argentina, Messrs. Moore and Abbot returned immediately to Calama.

Measurements of the Solar Constant of Radiation at Calama, Chile.—When Dr. Abbot reached Calama he found that Messrs. Moore and Abbot had prepared data giving the pyrheliometry, the transparency of the atmosphere for nearly 40 wave lengths, the function ρ/ρ_{sc} , and pyranometer values representing the intensity of the radiation of the sky in a zone 15° wide surrounding the sun. All these values were tabulated with solar constant values for 60 days of observation and for each day at periods when the air masses were 2 and 3, respectively.

We have felt very keenly the desirability of devising some method of determining the solar constant of radiation which would be independent of changes in the transparency of the atmosphere during the period of observation. It had been hoped that this might be done in some simple way by the aid of the pyranometer, that instrument which we devised several years ago for the purpose of measuring the brightness of the sky. It is well known that when the sky becomes more hazy the direct beam of the sun is reduced in intensity, but the scattered light of the sky at the same time is increased. Ac-

cordingly, it would seem that a pyranometer measurement of the brightness of a limited area of the sky near the sun would furnish an index of the state of the transparency of the atmosphere at the moment of observation, and this combined with the usual observations of the solar intensity at the earth's surface by the pyr heliometer, and combined further with the determination of the quantity of the aqueous vapor between the observer and sun (which is indicated by the state of the great infra-red absorption bands, ρ and φ) might give the means of estimating the solar radiation outside the atmosphere from observations made at a single instant of time.

With the various data mentioned above as a basis, the writer endeavored to find some method of determining the solar constant of radiation without the necessity of treating the several wave lengths of radiation separately, but after almost a week spent in working over the data, trying to combine them along these lines, the effort had to be abandoned. Mr. Moore had, however, suggested that if we knew the coefficient of atmospheric transmission for all of the individual wave lengths on a given day and had observed with the spectrobolometer and pyr heliometer at air mass 2 or at air mass 3, we could determine the solar constant from these data at once. All simple means having failed to give a satisfactory method, Mr. Moore's suggestion was acted upon, and it was found possible, by noting the value of the function ρ/ρ_{sc} and the intensity of the sky light in the neighborhood of the sun, to determine at once the transmission coefficients for all wave lengths. This we do by means of plots in which the data for the 60 days mentioned are employed. These data were used in the following manner:

Taking the value obtained at air mass 2 by the pyranometer for the limited area of sky around the sun, dividing it by the value of ρ/ρ_{sc} at the corresponding time, we obtain a function which we may call "F." Plotting values of "F" as abscissæ against values of the transmission coefficients for each measured wave length as ordinates, we obtain about 40 plots. These for the infra-red region of the spectrum are nearly straight lines but they become more and more convex toward the axes of coordinates for the rays of shorter wave lengths. In the 60 days which were available for the investigations the function "F" ranged through values running from 100 to 900 of a certain scale, while the function "a"—that is, the transmission coefficient—ranged only through a very few per cent and for a large portion of the spectrum, including the infra-red region, hardly through more than 1 or 2 per cent. Accordingly great error is allowable in the function "F" without greatly affecting the accuracy of the inference as to the value of the function "a." In short, by means of the function "F" we are able to determine the function "a" for all wave lengths with highly satisfactory accuracy from observations at a

single point of time, so that changes of the atmospheric transparency during the period of observation are avoided.

This new method will hereafter be employed by the Smithsonian observers at Calama in combination with the old, not only for air mass 2, but for air mass 3, and they will check one against the other frequently for a considerable period of time until we are abundantly satisfied of the accuracy of the new method of observation. Hitherto the new method has enabled us to save at Calama a number of days of observation which, owing to the obvious changes in transparency of the atmosphere, due to formation or disappearance of clouds, would otherwise have been lost.

So far as we have as yet been able to compare the results by the old and the new methods, they are on the average closely identical. For instance, on July 1 three values of the solar constant were computed: (1) By the old process; (2) from observation at air mass 2; (3) from observations at air mass 3. The results obtained were as follows: 1.948, 1.940, 1.955, all agreeing within less than 1 per cent, and the mean of the results by the new process agreeing identically with the result by the old.

The new process requires but two or three hours of work, where the old required about 15, so that if it continues to appear as satisfactory as now a very great gain in labor will result from it. Not only is this so, but a still greater gain we think will come in accuracy, for we have now eliminated the fruitful source of error, depending on the variability of the atmospheric transparency during the observations.

The new method of determining the solar constant of radiation is not applicable to other stations than Calama without a new series of contemporaneous solar constant determinations by the old method and pyranometer observations at air mass 2 and air mass 3 to use with them. We have not at present available the necessary pyranometer observations at Mount Wilson, but we shall undertake to obtain them at the earliest practicable moment, and hereafter it is probable that the new method of determination will be employed there as well as in South America.

On the whole, the expedition to South America was unexpectedly fruitful. First, satisfactory observations were made of the eclipse, including both photographic observations of the eclipse phenomenon and pyranometer observations of the brightness of the sky during its progress. Second, a very interesting conference was held with the chief and chief forecaster of the Argentine meteorological service, in which they explained their investigations of the application of solar radiation measurements to weather forecasts and indicated their high sense of the value of solar radiation work for weather

forecasting. Third, investigations at Calama based upon the observations there indicated a new empirical method of determining the solar constant of radiation, which appears to be equally as accurate as the old and to have the great advantages: (1) That it avoids the assumption of uniformity of atmospheric transparency during the several hours formerly required for observing, and (2) that it diminishes the time required for computing the result from about 15 hours to about 3 hours.

PERSONNEL.

Miss Florence A. Graves, computer, was placed on furlough beginning September 5, 1918, in order that she might take up work in connection with the Red Cross operations in France.

Miss Gladys L. Thurlby reported as assistant computer on December 2, 1918, and Miss Inez A. Ensign reported as computer on February 1, 1919.

SUMMARY.

At Washington, outside of the usual reductions of observations and various pieces of experimental investigation, some connected with the war, others with the study of radiation, but for which, for one reason or another, no definite result can at present be reported, progress has been made with the preparation of a new optical medium, potassium iodide, for the investigation of the rays beyond where rock salt is transmissible, and a new instrument based upon the principle of the perfect radiator or "absolutely black body" has been prepared and is undergoing test for the purpose of measuring nocturnal radiation such as the earth sends out to space.

At Mount Wilson the measurements of the solar constant of radiation have been continued, and a very neat and excellent piece of work has been done by Mr. Aldrich, in cooperation with the Army Balloon School at Arcadia, on the measurement of the reflection of sun and sky radiation from great sheets of clouds, which lead to the result that a fully clouded earth would reflect to space 78 per cent of the radiation of the sun falling upon it.

In South America, a successful expedition by Dr. Abbot observed the total eclipse of the sun on May 29 at La Paz, Bolivia. Good photographs of the phenomenon and also pyranometric observations by Mr. A. F. Moore of the brightness of the sky were obtained during the progress of the eclipse. A conference which is likely to prove of great future value was held by Dr. Abbot with the chief and chief forecaster of the Argentine meteorological service with reference to the employment of solar radiation measurements for weather forecasting. At Calama, Chile, Dr. Abbot, in cooperation with the Smithsonian observers there, Messrs. Moore and Abbot, devised a

new method of reducing solar radiation observations so as to determine the solar constant of radiation with at least equal precision to that obtained by the older method, and the advantages (1) that the new method is independent of the variability of atmospheric transparency, and (2), that it requires only about one-fifth as much time as the old.

Respectfully submitted.

C. G. ABBOT,

Director, Astrophysical Observatory.

Dr. C. D. WALCOTT,

Secretary, Smithsonian Institution.

APPENDIX 6.

REPORT ON THE LIBRARY.

SIR: I have the honor to submit the following report on the activities of the library of the Smithsonian Institution during the fiscal year ended June 30, 1919:

The receipts of publications during the year numbered 24,670 packages. Of these, 23,517 were received by mail and 1,153 through the international exchanges. Five hundred and sixty-one volumes were completed and 11,443 periodicals were entered.

SMITHSONIAN LIBRARY.

Main library.—Publications for the Smithsonian Main Library, after entry on the records, are forwarded to the Library of Congress for the Smithsonian deposit. The accession numbers for the year extended from 529,925 to 532,002. The accessions included 1,883 volumes, 242 parts of volumes, 348 pamphlets, and 87 charts.

The cataloguing covered 2,490 volumes and 85 charts; 1,621 volumes were recatalogued; 4,909 cards were typewritten, and 895 printed cards from the Library of Congress for publications deposited by the institution were filed in the catalogue; 5,721 public documents were presented to the Library of Congress in accordance with the established practice.

The securing of publications in exchange for Smithsonian publications was carried on under war conditions with results that fully warranted the effort, and the completion of sets in the Smithsonian deposit of the Library of Congress has been continued, with the following results:

Number of want cards received from Library of Congress:

From Smithsonian Division.....	86
From Periodical Division.....	129
From Order Division.....	14
	229

Number of publications secured for Library of Congress:

	Volume.	Parts.
For Smithsonian Division.....	94	331
For Periodical Division.....	6	145
For Order Division.....	32	1
	132	527

Number of sets completed, 61.

Office reference library.—The accessions for the office library, which includes the Astrophysical Observatory and the National Zoological Park, amounted to 639 publications, distributed as follows: Office library, 358 volumes and 20 pamphlets; Astrophysical Observatory, 89 volumes, 11 parts, 18 pamphlets; National Zoological Park, 140 volumes and 3 pamphlets. There was a circulation of 146 volumes.

Aeronautical collection.—Continued interest has been manifested in the institution's collection of aeronautical publications, which has been of special value to aeronautical-research workers in the Army, the Navy, and scientific institutions. Seventy-eight titles have been added during the year. The Bibliography of Aeronautics, completed last year, is being printed by the National Advisory Committee for Aeronautics, and will be ready for distribution shortly.

Reading room.—No new titles of particular interest have been added to the reading room during the year. In the interest of war-time economy on the part of the publishers, several popular magazines were not received in exchange. The number of magazines loaned during the year was 3,140.

Employees' library.—The number of loans in the employees' library was 332. The collection has been recatalogued, classified, and rearranged on the shelves. The volumes in the stacks are being rearranged, so that the magazines in greatest demand will be rendered more accessible.

Art room.—The collection in the art room, including the pieces of statuary as well as the books, have been carefully gone over during the year, and those that could not be considered as relating to the fine arts were sent elsewhere in order to make room for material which should be placed here. The large cases were remodeled in order to take care of the large portfolios of prints, especially those of the Marsh collection, and other books which should be under cover. The whole contents of this room is rearranged, catalogued, classified, and put in thorough order.

De Peyster collection.—Author cards for 1,722 titles of books in the De Peyster collection have been made, and the volumes on French history, numbering 869 titles, have been arranged on the shelves and rendered accessible.

NATIONAL MUSEUM LIBRARY.

The loans made by the Museum library during the year were 13,913, an increase over last year of 2,676. There were catalogued 1,048 volumes, 3,229 pamphlets; 62 volumes and 115 pamphlets were recatalogued; 1,322 volumes were sent to the Government bindery and 710 returned.

The most important acquisition was a set of catalogues of the J. Pierpont Morgan art collection, presented by J. Pierpont Morgan,

jr. The set numbers 29 volumes, many of them privately printed in numbered editions. Acknowledgment is due the University of Michigan for the gift of the 12 volumes published of the Humanistic Series.

The accessions were further increased by transfers from the Hygienic Laboratory, and contributions from Mr. B. H. Swales, the estate of Dr. Richard Rathbun, Dr. C. D. Walcott, Mr. William Schaus, Dr. O. P. Hay, Dr. C. W. Richmond, Dr. W. H. Dall, Dr. Mary J. Rathbun, Mr. A. H. Clark, Mr. W. R. Maxon, and others.

There were accessioned during the year 2,172 volumes, 2,585 pamphlets, 29 parts of volumes. The number of books in the library now is 141,794, consisting of 54,685 volumes and 87,109 pamphlets and unbound papers.

Technological series.—Additions to the technological library number 346 volumes, 4,096 parts of volumes, and 750 pamphlets. Current periodicals entered and shelved number 56 volumes and 3,091 parts of volumes. The back file of periodicals in the stacks have been examined and recorded from earliest issued to date. Entry was made for 4,249 volumes and 6,172 parts of volumes not entered before in the periodical record. The record of all periodicals is now complete and will be kept up to date for reference and consultation; 885 cards were added to the catalogue, 362 being for new material and the remainder of class 500.

In the scientific depository catalogue 10,230 cards were received, arranged, and filed. Of these 3,032 were main author cards, subject headings and titles being added for 7,198 additional cards in accordance with the plan of a dictionary catalogue.

The books and periodicals loaned during the year number 121 volumes, 21 pamphlets, and 104 periodicals or parts of volumes, making a total circulation of 245.

Sectional library, Division of Plants.—The revision of the books, serials, and periodicals in the Division of Plants has been satisfactorily completed. A card catalogue has been made of all of the books in the sectional library, numbering 896 titles, or 1,308 volumes. A periodical card record has been made for the recording of all volumes and parts of volumes now in the section, and current numbers are to be entered as received. The total number of publications thus recorded is 781 volumes and 153 parts of volumes. All completed volumes of unbound periodicals, numbering 38, have been collated and sent to the bindery.

In the course of revision, 104 volumes were transferred from the main library to the sectional library, inasmuch as they proved to be of special value to the division, and 64 volumes of lesser direct bearing on the division's work were transferred to the stacks of the main library; 510 volumes of the recent Biltmore acquisition were re-

bound or repaired and placed on the shelves either in the sectional library or in the main library stack rooms.

The entire collections have been gathered together and shelved in alphabetical order in the old regents' room, with the exception of a small number of books kept in adjoining offices, where they are especially needed. A card catalogue case has been ordered and will be placed in the library room, to contain not only the catalogue of the sectional library of the Division of Plants but also a duplicate card catalogue which has been prepared of all books and periodicals of the main Museum library on the subject of botany. By collecting these and shelving them in the first floor stacks in the west end of the Smithsonian Building, next to the John Donnell Smith collection, all the available works on botanical subjects have been brought together and rendered readily accessible.

Sectional libraries.—Following is a complete list of sectional libraries:

Administration.	History.	Parasites.
Administrative assist-	Insects.	Photography.
ant's office.	Invertebrate paleon-	Physical anthropology.
Anthropology	tology.	Prehistoric archeology.
Biology.	Mammals.	Property clerk.
Birds.	Marine invertebrates.	Registrar's office.
Botany.	Materia medica.	Reptiles and batrachians.
Comparative anatomy.	Mechanical technology.	Superintendent's office.
Editor's office.	Mesozoic fossils.	Taxidermy.
Ethnology.	Mineral technology.	Textiles.
Fishes.	Minerals.	Vertebrate paleontology.
Food	Mollusks.	War library.
Geology.	Oriental archeology.	Wood technology.
Graphic arts.	Paleobotany.	

BUREAU OF AMERICAN ETHNOLOGY LIBRARY.

A report of the operations of the library of the Bureau of American Ethnology will be found in the report of that bureau. This library is administered under the direct care of the ethnologist in charge.

ASTROPHYSICAL OBSERVATORY LIBRARY.

The collection of reference works relating to astrophysics has been in constant use. Eighty-nine volumes, 11 parts of volumes, and 18 pamphlets were accessioned during the year.

NATIONAL ZOOLOGICAL PARK LIBRARY.

The library of the National Zoological Park made an increase during the year of 140 volumes and 3 pamphlets. This library is not extensive, but is simply a working library.

SUMMARY OF ACCESSIONS.

The accessions during the year, with the exception of the library of the Bureau of American Ethnology, may be summarized as follows:

To the Smithsonian deposit in the Library of Congress, including parts to complete sets-----	2, 077
To the Smithsonian office, Astrophysical Observatory, and National Zoological Park-----	639
To the United States National Museum-----	4, 786
	<hr/> 7, 502

Respectfully submitted.

PAUL BROCKETT,
Assistant Librarian.

Dr. CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

APPENDIX 7.

REPORT ON THE INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

SIR: I have the honor to submit the following report on the operations of the United States Bureau of the International Catalogue of Scientific Literature for the fiscal year ending June 30, 1919.

Notwithstanding the fact that the war in Europe practically ceased when the armistice of November 11, 1918, was declared, international affairs are still in such a chaotic state that no reorganization of the International Catalogue has yet been possible. All of the regional bureaus are in practically the same condition as they were in 1918, and are having difficulty in obtaining suitable aid to carry on their work. These conditions also greatly hamper the work of the Central Bureau in London, which, in addition, is faced with the pressing need of greater financial assistance.

The receipts of the London Central Bureau, whose sole support is derived from sales of the catalogue to the various subscribers throughout the world, have been greatly curtailed and unless subscriptions increase or the bureaus of Germany, Austria, Hungary, Poland, Belgium, and Russia, who are in arrears to the extent of almost \$9,000 per annum, again contribute their support it will be necessary to obtain assistance from some other source to finance the enterprise after the publication of the fourteenth annual issue.

Since the publication of the last annual report of this bureau eight volumes of the catalogue have been published, which completes the work through the thirteenth annual issue, with the exception of one volume, that of physiology. Twelve of the 17 volumes of the fourteenth annual issue have been published.

This bureau has continued to collect and classify the publications of the United States, and has now on hand a great quantity of material for the future volumes of the catalogue; indeed, in spite of war conditions, some of the sciences, notably zoology, have been indexed far in advance of the published volumes.

It has been evident ever since the beginning of the war that there would have to be a general reorganization of the catalogue when international affairs become sufficiently settled to enable the various countries taking part in the enterprise to decide how much aid they can individually render in order that the ever-increasing literature

of science may be made available for general reference, and then through their representatives and delegates agree with the other nations on a plan to continue this great international index to science. Methods and means were very thoroughly considered before beginning the publication of the catalogue in 1901, and the methods then decided on and the classification schedules then published were probably at that time the best means of attaining the end sought; but the condition of the world and the methods and aims of scientific workers have now so changed that it is apparent that the organization and methods of the International Catalogue need revision. The Royal Society of London, which has been the principal sponsor of the catalogue since the beginning, has recently announced that after the completion of the fourteenth annual issue it will be necessary for some new financial agreement to be made in order to continue the work, and has requested the scientific academies throughout the world to offer suggestions as how best to accomplish the end in view.

It may be well to here consider the need and aim of an international organization to catalogue scientific literature.

Many of the greatest minds of the day are engaged in researches and investigations the results of which are finally published in some form. It is obvious that means should exist to enable other workers in the same or similar fields as well as the general reader to refer to these publications.

Revolutionizing advances in many of the arts, industries, and trades are often made by means of scientific research, and what to-day appears to be an abstract investigation in pure science to-morrow becomes a stepping-stone to some epoch-making invention which either entirely changes an old or establishes a new trade or industry. This was true even before the present war, but since then cases of such revolutionary discoveries have multiplied to such an extent that it is hardly necessary to cite examples. All of the sciences have their special journals, many of which publish very complete indexes and even abstracts likely to be of interest to the specialists in various sciences, but there is no publication similar to the International Catalogue of Scientific Literature, whose aim is to index and classify all of the literature of the pure sciences of the world. It has been one of the aims of the catalogue since the beginning to cooperate with the editors and publishers of other similar indexes in order to obviate duplication of labor. Cooperation of this kind has been accomplished in several cases, notably that of the Zoological Record, which from 1906 to 1914 was published through the cooperation of the International Catalogue and the Zoological Society of London, with the result that the combined volume was universally acknowledged

to be far superior to any index of the kind ever published or, indeed, attempted. At the convention held in London in 1910 a committee was appointed and authorized to form similar combinations with the publishers of other indexes and yearbooks, but, unfortunately, for various reasons it has not yet been possible to form such combinations to the extent authorized by the convention.

Very respectfully, yours,

LEONARD C. GUNNELL,
Assistant in Charge.

Dr. CHARLES D. WALCOTT,
Secretary Smithsonian Institution.

APPENDIX 8.

REPORT ON THE PUBLICATIONS.

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and its branches during the year ending June 30, 1919:

The Institution proper published during the year 10 papers in the series of Miscellaneous Collections, pamphlet copies of 2 Annual Report separates, and 1 special publication. The Bureau of American Ethnology published 5 bulletins, 1 Annual Report, and 1 advance extract from the volume. The United States National Museum issued 2 annual reports, 2 volumes of the proceedings, 48 separate papers forming parts of these and other volumes, 6 bulletins, and 20 separate parts of other bulletins.

The total number of copies of publications distributed by the Institution and its branches was 161,288, which includes 404 volumes and separate memoirs of Smithsonian Contributions to Knowledge, 15,603 volumes and separate pamphlets of Smithsonian Miscellaneous Collections, 13,885 volumes and separate pamphlets of Smithsonian Annual Reports, 118,332 volumes and separates of National Museum publications, 11,483 publications of the Bureau of American Ethnology, 1,444 special publications, 10 volumes of the Annals of the Astrophysical Observatory, 69 reports of the Harri-man Alaska Expedition, and 58 reports of the American Historical Association.

SMITHSONIAN MISCELLANEOUS COLLECTIONS.

Of the Miscellaneous Collections, volume 67, 1 paper was published; volume 68, 1 paper, title page, and table of contents; volume 69, 7 papers; volume 70, 1 paper; in all, 11 issues, as follows:

VOLUME 67.

No. 4. Cambrian Geology and Paleontology. IV, No. 4. Appendages of Trilobites. By Charles D. Walcott. December, 1918. 216 pp. (Publ. 2523.)

VOLUME 68.

Title page and table of contents. (Publ. 2526.) December 20, 1918.

No. 12. Explorations and Field-Work of the Smithsonian Institution in 1917. 134 pp. (Publ. 2492.) July 24, 1918.

VOLUME 69.

No. 2. The Mosses Collected by the Smithsonian African Expedition, 1909-10. By H. N. Dixon. October 8, 1918. 30 pp. (Publ. 2494.)

No. 4. Early Mesozoic Physiography of the Southern Rocky Mountains. By Willis T. Lee. July, 1918. 50 pp. (Publ. 2497.)

No. 8. Uganda Mosses Collected by R. Dümmer and others. By H. N. Dixon. Oct. 21, 1918. 11 pp. (Publ. 2522.)

No. 9. The Smithsonian Eclipse Expedition of June 8, 1918. By L. B. Aldrich. March 5, 1919. 22 pp. (Publ. 2527.)

No. 10. The Reflecting Power of Clouds. By L. B. Aldrich. February 10, 1919. 9 pp. (Publ. 2530.)

No. 11. The Races of Russia. By Aleš Hrdlička. March, 1919. 21 pp. (Publ. 2532.)

No. 12. Begoniaceae Centrali-Americanae et Ecuadorenses. By Casimir de Candolle. April 9, 1919. 10 pp. (Publ. 2533.)

VOLUME 70.

No. 1. A Lower Cambrian Edrioasterid (*Stromatocystites walcotti*). By Charles Schuchert. May 8, 1919. 9 pp. (Publ. 2534.)

SMITHSONIAN ANNUAL REPORTS.

Report for 1917.

The general appendix of the report for 1917, which was still in press at the end of the year, contains the following papers:

Projectiles Containing Explosives, by Commandant A. R.

Gold and Silver Deposits in North and South America, by Waldemar Lindgren.

The Composition and Structure of Meteorites Compared with that of Terrestrial Rocks, by George P. Merrill.

Corals and the Formation of Coral Reefs, by Thomas Wayland Vaughan.

The Correlation of the Quaternary Deposits of the British Isles with those of the Continent of Europe, by Charles E. P. Brooks.

Floral Aspects of the Hawaiian Islands, by A. S. Hitchcock.

Natural History of Paradise Key and the near-by Everglades of Florida, by W. E. Safford.

Notes on the Early History of the Pecan in America, by Rodney H. True.

The Social, Educational, and Scientific Value of Botanic Gardens, by John Merle Coulter.

Bird Rookeries of the Tortugas, by Paul Bartsch.

An Economic Consideration of Orthoptera directly Affecting Man, by A. N. Caudell.

An Outline of the Relations of Animals to their Inland Environments, by Charles C. Adams.

The National Zoological Park: A Popular Account of its Collections, by N. Hollister.

Ojibway Habitations and other Structures, by David I. Bushnell, jr.

The Sea as a Conservator of Wastes and a Reservoir of Food, by H. F. Moore.

National Work at the British Museum—Museums and Advancement of Learning, by F. A. Bather.

Leonhard Fuchs, physician and botanist, by Felix Neumann.

In memoriam: Edgar Alexander Mearns, by Charles W. Richmond.

William Bullock Clark.

REPORT FOR 1918.

The report of the executive committee and proceedings of the Board of Regents of the Institution and report of the secretary, both forming part of the annual report of the Board of Regents to Congress, were issued in pamphlet form in December, 1918.

Report of the executive committee and proceedings of the Board of Regents of the Smithsonian Institution for the year ending June 30, 1918. 13 pp. (Publ. 2529.)

Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1918. 101 pp. (Publ. 2487.)

The general appendix of the report for 1918, which was in press at the close of the year, contains the following papers:

1. The Discovery of Helium, and what came of it, by C. G. Abbot.
2. An Account of the Rise of Navigation, by R. H. Curtiss.
3. The Tornadoes of the United States, by Robert DeC. Ward.
4. Wind Power, by James Carlill.
5. A Tribute. Samuel Pierpont Langley: Pioneer in Practical Aviation, by Henry Leffmann.
6. Modern Physics, by R. A. Millikan.
7. The Experiments of Dr. P. W. Bridgman on the Properties of Matter When Under High Pressure. Introductory note, by C. G. Abbot.
8. The problem of Radioactive Lead, by Theodore W. Richards.
9. Sphagnum Moss; war substitute for cotton in absorbent surgical dressings, by George E. Nichols.
10. History of Military Medicine and Its Contributions to Science, by Col. W. P. Chamberlain.
11. Some Problems of International Readjustment of Mineral Supplies as Indicated in Recent Foreign Literature, by Eleanor F. Bliss.
12. Reptile Reconstructions in the United States National Museum, by Charles W. Gilmore.
13. A Pleistocene Cave Deposit of Western Maryland, by J. W. Gidley.
14. Paleobotany: A Sketch of the Origin and Evolution of Floras, by Edward W. Berry.
15. The Direct Action of Environment and Evolution, by Prince Kropotkin.
16. The Law of Irreversible Evolution, by Branislav Petronievics.
17. The Fundamental Factor of Insect Evolution, by S. S. Chetverikov.
18. The Psychic Life of Insects, by E. L. Bouvier.
19. Sexual Selection and Bird Song, by Chauncey J. Hawkins.
20. Marine Camouflages and their Camouflage: The present and prospective significance of facts regarding coloration of tropical fishes, by W. H. Longley.
21. Foot-Plow Agriculture in Peru, by O. F. Cook.
22. Sun Worship of the Hopi Indians, by J. Walter Fewkes.
23. The League of the Iroquois and its Constitution: A constitutional league of peace in the Stone Age of America, by J. N. B. Hewitt.
24. The Problem of Degeneracy, by H. F. Tredgold.
25. History in Tools, by W. M. Flinders Petrie.
26. The Background of Totemism, by E. Washburn Hopkins.
27. A Great Naturalist: Sir Joseph Hooker, by Sir E. Ray Lankester.

SPECIAL PUBLICATIONS.

The following publication was issued in octavo form:

Classified list of Smithsonian publications available for distribution October 15, 1918. 1918. 31 pp. (Publ. 2524.)

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM.

The publications of the National Museum are: (a) The annual report to Congress; (b) The Proceedings of the United States National Museum; and (c) The Bulletin of the United States National Museum, which includes the Contributions from the United States National Herbarium. The editorship of these publications is vested in Dr. Marcus Benjamin.

During the year the museum published 2 annual reports, 2 volumes of the proceedings, 48 separate papers forming parts of these and other volumes, 6 bulletins, and 20 separate parts of other bulletins.

The issues of the proceedings were as follows: Volumes 52 and 53 complete.

The issues of the bulletins were as follows:

Bulletin 50, Part VIII. The Birds of North and Middle America, by Robert Ridgway.

Bulletin 99. East African Mammals in the United States National Museum; Part I, Insectivora, Chiroptera, and Carnivora; and Part II, Rodentia, Lagomorpha, and Tubulidentata, by N. Hollister.

Bulletin 100. Contributions to the Biology of the Philippine Archipelago and Adjacent Regions. Volume 1, part 4: Report on the Chaetognatha collected by the United States Fisheries Steamer *Albatross* during the Philippine Expedition, 1907-1910, by Ellis L. Michael; part 5, Hydromedusae, Siphonophores, and Ctenophores of the *Albatross* Philippine Expedition, by Henry B. Bigelow. Volume 2, part 1: The Salpidae collected by the United States Fisheries Steamer *Albatross* in Philippine waters during the years 1908 and 1909, by Maynard M. Metcalf; part 2: The Salpidae—a taxonomic study, by Maynard M. Metcalf and Mary M. Bell. Volume 3: Contributions to the Biology of the Philippine Archipelago and Adjacent Regions. Starfishes of the Philippine Seas and Adjacent Waters, by Walter K. Fisher.

Bulletin 102, volume 1. The Energy Resources of the United States—a field for reconstruction, by Chester G. Gilbert and Joseph E. Pogue. Also, The Mineral Industries of the United States. Part 5: Power—its significance and needs, by Chester G. Gilbert and Joseph E. Pogue. Part 6: Petroleum—a Resource Interpretation, by Chester G. Gilbert and Joseph E. Pogue. Part 7: Natural Gas—its production, service, and conservation, by Samuel S. Wyer.

Bulletin 103. Contributions to the Geology and Paleontology of the Canal Zone, Panama, and geographically related areas in Central America and the West Indies, represents the work of a number of specialists, whose papers were issued, in separate form, as follows:

Pages 1-13: On some fossil and recent Lithothamnicae of the Panama Canal Zone, by Marshall A. Howe.

Pages 15-44: The Fossil Higher Plants from the Canal Zone, by Edward W. Berry.

Pages 45-87: The Smaller Fossil Foraminifera of the Panama Canal Zone, by Joseph Augustine Cushman.

Pages 89-102: The Larger Fossil Foraminifera of the Panama Canal Zone, by Joseph Augustine Cushman.

Pages 103-116: Fossil Echini of the Panama Canal Zone and Costa Rica, by Robert Tracy Jackson.

Pages 117-122: Bryozoa of the Canal Zone and related areas, by Ferdinand Canu and Ray S. Bassler.

Pages 123-184: Decapod Crustaceans from the Panama Region, by Mary J. Rathbun.

Pages 185-188: Cirripedia from the Panama Canal Zone, by H. A. Pilsbry.

Pages 525-545: The Sedimentary Formations of the Panama Canal Zone, with special reference to the Stratigraphic relations of the fossiliferous beds, by Donald Francis MacDonald.

Pages 547-612: The Biologic Character and Geologic Correlation of the Sedimentary Formation of Panama in their relation to the geologic history of Central America and the West Indies, by Thomas Wayland Vaughan.

Bulletin 104 (one part). The Foraminifera of the Atlantic Ocean, by Joseph Augustine Cushman, viz: Part 1, "Astrorhizidae," was issued. Of the remaining separates, two formed parts of volume 20, Contributions from the United States National Herbarium, while 19 were from volume 54, and 29 from volume 55 of the Proceedings.

Bulletin 105. Catalogue of the Postage Stamps and Stamped Envelopes of the United States and Possessions, issued prior to January 1, 1919, by Josiah B. Leavy.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY.

The publications of the bureau are discussed in Appendix 2. The editorial work of the bureau is in charge of Mr. Stanley Searles, editor.

During the year five bulletins, the Thirty-second Annual Report, an advance extract from this report, and a list of publications were issued, as follows:

Bulletin 59. Kutenai Tales. Franz Boas. 1918. 387 pp.

Bulletin 61. Teton Sioux Music. Frances Densmore. 1918. 561 pp., 82 plates.

Bulletin 64. The Maya Indians of Southern Yucatan and Northern British Honduras. Thomas W. F. Gann. 1918. 146 pp., 28 plates.

Bulletin 65. Archeological Explorations in Northeastern Arizona. Alfred Vincent Kidder and Samuel J. Guernsey. 1918. 228 pp., 97 plates.

Bulletin 66. Recent Discoveries Attributed to Early Man in America. Aleš Hrdlička. 1918. 67 pp., 14 plates.

Introduction to Seneca Fiction, Legends, and Myths. Collected by Jeremiah Curtin and J. N. B. Hewitt. Edited by J. N. B. Hewitt. 1919. An advance separate from the Thirty-second Annual Report. 71 pp.

Thirty-second Annual Report—Accompanying paper: Seneca Fiction, Legends, and Myths. (Hewitt and Curtin.) 819 pp.

List of publications of the bureau.

There are at present in press five annual reports, and nine bulletins as follows:

Bulletin 60. Handbook of Aboriginal American Antiquities. Part 1 (Holmes).

Bulletin 67. Alsea Texts and Myths (Frachtenberg).

Bulletin 68. Structural and Lexical Comparison of the Tunica, Chitimacha, and Atakapa Languages (Swanton).

Bulletin 69. Native Villages and Village Sites East of the Mississippi (Bushnell).

Bulletin 70. Prehistoric Villages, Castles, and Towers (Fewkes).

Bulletin 71. Native Cemeteries and Forms of Burial East of the Mississippi (Bushnell).

Bulletin 72. The Owl Sacred Pack of the Fox Indians (Michelson).

Bulletin ---. Handbook of the Indians of California (Kroeber).

Bulletin ---. Northern Ute Music (Densmore).

REPORT OF THE AMERICAN HISTORICAL ASSOCIATION.

The annual reports of the American Historical Association are transmitted by the association to the secretary of the Smithsonian Institution and are communicated to Congress under the provisions of the act of incorporation of the association.

Volume 1 of the report for 1916 was published during the year, and volume 2 of the same report was in press on June 30.

REPORT OF THE NATIONAL SOCIETY OF THE DAUGHTERS OF THE AMERICAN REVOLUTION.

The manuscript of the twenty-first annual report of the National Society of the Daughters of the American Revolution was transmitted to Congress according to law shortly after the close of the fiscal year.

THE SMITHSONIAN ADVISORY COMMITTEE ON PRINTING AND PUBLICATION.

The editor has continued to serve as secretary of the Smithsonian advisory committee on printing and publication. This committee passes on all manuscripts offered for publication by the Institution or its branches, and considers forms of routine, blanks, and various other matters pertaining to printing and publication. Thirteen meetings were held during the year and 79 manuscripts were acted upon.

Respectfully submitted.

W. P. TRUE, *Editor.*

To Dr. CHARLES D. WALCOTT,

Secretary of the Smithsonian Institution.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1919.

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds, receipts, and disbursements of the Institution and a statement of the appropriations by Congress for the National Museum, the international exchanges, the Bureau of American Ethnology, the National Zoological Park, the Astrophysical Observatory, the International Catalogue of Scientific Literature, etc., for the year ending June 30, 1919, together with balances of previous appropriations:

SMITHSONIAN INSTITUTION.

Condition of the fund July 1, 1919.

In addition to the total sum of \$1,000,000 deposited in the Treasury of the United States, and authorized under section 5591, Revised Statutes, the details of which were given in our last report, there has accumulated from incomes, bequests, and by transfer the sum of \$74,794.38, which has been invested in bonds of approved character for the following specific accounts and carried on the books of the Institution as the consolidated fund, viz:

Hodgkins general fund.....	\$37, 275. 00
Rhees fund.....	74. 00
Avery fund.....	14, 824. 45
Addison T. Reid fund.....	1, 348. 00
Lucy T. and George W. Poore fund.....	2, 819. 00
George K. Sanford fund.....	142. 00
Smithson fund.....	984. 00
Chamberlain fund.....	10, 000. 00
Bruce Hughes fund.....	7, 327. 93
Total	74, 794. 38

One of the pieces of real estate bequeathed to the Institution by the late Robert Stanton Avery has been sold and the proceeds rein-

vested in bonds comprising the consolidated fund. Only a single parcel of ground with improvements thereon remains of the several bequeathed to the Institution by this benefactor.

Among the assets comprising the Lucy T. and George W. Poore fund were several lots of unimproved property near the city of Lowell, Mass. A part of these lots have been sold during the year, and the sum of \$520.50 was realized.

Statement of receipts and disbursements from July 1, 1918, to June 30, 1919.

RECEIPTS.

Cash on deposit and in safe July 1, 1918	\$1,289.90
Interest on fund in United States Treasury— \$60,000.00	
Other interest	4,466.94
	<hr/> \$64,466.94
Repayments, rentals, publications, etc.	34,723.33
Contributions for specific purposes	26,343.26
Bills receivable	15,000.00
Proceeds from sale of real estate	3,567.00
	<hr/> 144,100.53
	<hr/> 145,390.43

DISBURSEMENTS.

Buildings, care and repairs	6,946.48
Furniture and fixtures	1,634.29
General expenses:	
Salaries	17,671.70
Meetings	126.00
Stationery	721.47
Postage, telegraph, and telephone	766.09
Freight	84.58
Incidentals, fuel, and lights	1,388.93
Garage	2,674.51
	<hr/> 23,433.28
Library	2,581.81
Publications and their distribution:	
Miscellaneous collections	5,060.54
Special publications	225.25
Publication supplies	336.66
Salaries	5,696.17
Harriman publications	49.45
	<hr/> 11,368.07
Explorations, researches, and collections	3,647.00
Hodgkins specific fund, researches, and publications	5,049.33
International exchanges	655.89
Gallery of art	26.00
Consolidated (fund (invested))	5,670.00
Bills receivable—time certificates	25,000.00
Interest accrued—consolidated fund	107.50
Advances for field expenses, etc.	57,148.00
	<hr/> 143,267.65

Deposited with Treasurer of the United States and in bank.....	\$1, 922. 78
Cash on hand.....	200. 00
	<hr/> \$2, 122. 78
	<hr/> 145, 390. 43

The itemized report of the auditor confirms the foregoing statement of receipts and expenditures, and is approved. A summary of the report follows:

CAPITAL AUDIT CO.,
METROPOLITAN BANK BUILDING,
Washington, D. C.

EXECUTIVE COMMITTEE, BOARD OF REGENTS, SMITHSONIAN INSTITUTION.

SIRS: We have examined the accounts and vouchers of the Smithsonian Institution for the fiscal year ended June 30, 1919, and certify the following to be a correct statement:

Total receipts.....	\$144, 100. 53
Total disbursements.....	143, 267. 65
	<hr/> 832. 88
Excess of receipts over disbursements.....	
Amount from July 1, 1918.....	1, 289. 90
	<hr/> 2, 122. 78
Balance on hand June 30, 1919.....	
	<hr/> 3, 779. 06
Balance, as shown by treasurer's statement, as of June 30, 1919.....	
Less outstanding checks.....	3, 304. 73
	<hr/> 474. 33
Balance.....	
Balance, American National Bank.....	1, 448. 45
Cash on hand.....	200. 00
	<hr/> 2, 122. 78
Balance June 30, 1919.....	

The vouchers representing payments from the Smithsonian income during the year, each of which bears the approval of the secretary or, in his absence, of the acting secretary, and a certificate that the materials and services charged were applied to the purposes of the Institution, have been examined in connection with the books of the Institution and agree with them.

CAPITAL AUDIT CO.,
By WILLIAM L. YAFGER, *President.*

All payments are made by check, signed by the secretary, on the Treasurer of the United States, and all revenues are deposited to the credit of the same account, except in some instances small deposits are now made in bank for convenience of collection.

The practice of investing temporarily idle funds in time deposits has proved highly satisfactory. During the year the interest derived from this source has amounted to \$1,048.10.

Your committee also presents the following summary of appropriations for the fiscal year 1919 intrusted by Congress to the care of the Smithsonian Institution, balances of previous appropriations at the beginning of the fiscal year, and amounts unexpended on June 30, 1919:

	Available after July 1, 1918.	Balance June 30, 1919.
International exchanges, 1917.....	\$859.93	¹ \$859.93
International exchanges, 1918.....	5,296.80	893.24
International exchanges, 1919.....	35,000.00	3,794.55
American Ethnology, 1917.....	138.31	¹ 119.71
American Ethnology, 1918.....	3,817.51	430.21
American Ethnology, 1919.....	42,000.00	5,885.29
International Catalogue, 1917.....	226.77	¹ 6.24
International Catalogue, 1918.....	963.64	585.10
International Catalogue, 1919.....	7,500.00	1,186.75
Astrophysical Observatory, 1917.....	570.46	¹ 76.71
Astrophysical Observatory, 1918.....	1,771.14	230.67
Astrophysical Observatory, 1919.....	13,000.00	2,663.21
Observations, eclipse of sun, 1918.....	1,929.88	1,455.33
National Museum:		
Furniture and fixtures, 1917.....	18.97	¹ 18.97
Furniture and fixtures, 1918.....	6,845.77	48.14
Furniture and fixtures, 1919.....	15,000.00	910.99
Heating and lighting, 1917.....	699.24	¹ 688.24
Heating and lighting, 1918.....	6,103.77	372.75
Heating and lighting, 1919.....	55,000.00	6,245.76
Preservation of collections, 1917.....	647.87	¹ 243.34
Preservation of collections, 1918.....	12,903.59	4,943.88
Preservation of collections, 1919.....	300,000.00	33,383.19
Books, 1917.....	450.60	¹ 411.60
Books, 1918.....	1,227.60	292.80
Books, 1919.....	2,000.00	1,356.36
Postage, 1919.....	500.00	.....
Building repairs, 1917.....	195.59	¹ 195.59
Building repairs, 1918.....	2,174.38	46.37
Building repairs, 1919.....	10,000.00	3,530.84
National Zoological Park, 1917.....	83.30	¹ 83.30
National Zoological Park, 1918.....	9,743.24	2.53
National Zoological Park, 1919.....	115,000.00	10,534.95
Increase of compensation, 1919 (indefinite).....	.....	.....

¹ Carried to credit of surplus fund.

Statement of estimated income from the Smithsonian fund and from other sources, accrued and prospective, to be available during the fiscal year ending June 30, 1920.

Balance June 30, 1919.....	\$2,122.78
Bills receivable.....	\$30,000.00
Interest on fund deposited in United States Treasury due July 1, 1919, and Jan. 1, 1920.....	60,000.00
Interest from miscellaneous sources.....	4,048.00
Exchange repayments, sale of publications, refund of advances, etc.....	25,503.04
Deposits for specific purposes.....	16,500.00
	136,051.04
Total available for year ending June 30, 1920.....	138,173.82

Respectfully submitted.

GEO. GRAY,
ALEXANDER GRAHAM BELL,
Executive Committee.

PROCEEDINGS OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE FISCAL YEAR ENDING JUNE 30, 1919.

ANNUAL MEETING DECEMBER 12, 1918.

The board met at the Institution at 10 o'clock a. m.

Present: The Hon. Edward D. White, Chief Justice of the United States, chancellor, in the chair; the Hon. Thomas R. Marshall, Vice President of the United States; Senator Henry Cabot Lodge; Representative Lemuel P. Padgett; Representative Frank L. Greene; Dr. Alexander Graham Bell; Judge George Gray; Mr. Charles F. Choate, jr.; Mr. John B. Henderson; and the secretary, Mr. Charles D. Walcott.

DEATH OF REGENTS.

The secretary announced the death of Senator Stone, a regent for over five years.

Senator Lodge presented the following resolutions, which were adopted:

Whereas the Board of Regents of the Smithsonian Institution having learned of the death, on April 14, 1918, of the Hon. William Joel Stone, United States Senator from Missouri, and for over five years a member of this board:

Resolved, That the regents desire to place on record an expression of their deep regret at the passing away of their distinguished colleague;

Resolved, That this resolution be recorded in the proceedings of the board, and that a copy be transmitted by the secretary to the family of Senator Stone.

The death of the Hon. Charles Warren Fairbanks was announced.

Vice President Marshall submitted the following resolutions, which were adopted:

Whereas the Board of Regents of the Smithsonian Institution having learned of the death, on June 4, 1918, of the Hon. Charles Warren Fairbanks, one of their number:

Resolved, That the regents hear with profound sorrow of the passing away of their distinguished colleague, who, during two periods of his useful life was a member of this board; first, as vice president of the United States from 1905 to 1909 when he was ex officio a regent; next as a citizen regent from Indiana from 1912 to the date of his death. Mr. Fairbanks was always a force for good, and his loss is deeply felt by his colleagues;

Resolved, That this resolution be spread upon the records of the board, and that a copy be transmitted by the secretary to the family of our departed friend and coworker.

In this connection the secretary also announced the death of former regent Dr. Andrew D. White, who had served on the board for over 28 years, from 1888 to 1916.

Dr. Bell presented the following resolutions, which were unanimously adopted:

Whereas the Board of Regents of the Smithsonian Institution having learned of the death, on November 4, 1918, of Dr. Andrew Dickson White, a founder of Cornell University and its president for 18 years, preeminently distinguished also as a diplomat and as a publicist, a regent of the Smithsonian Institution from 1888 to 1916:

Resolved, That the board desire to place on record an expression of their sincere sorrow at the decease of their former colleague, who for over 28 years gave the benefit of his ripened wisdom to the affairs of the Institution, and whose death will be a most serious loss in the fields of learning, of diplomacy, and of citizenship;

Resolved, That this minute be placed upon the records of the board, and that a copy be transmitted by the secretary to the family of Dr. White.

APPOINTMENT OF REGENTS.

The secretary announced the appointment of regents, as follows:

By the President of the Senate, on May 10, 1918: The Hon. Charles S. Thomas, a Senator from Colorado, to succeed the Hon. William Joel Stone, deceased.

By the Speaker of the House of Representatives, on December 15, 1917: The Hon. Scott Ferris, to succeed himself; the Hon. Lemuel P. Padgett, to succeed Mr. James T. Lloyd, whose term as a Representative had expired; the Hon. Frank L. Greene, to succeed Mr. Ernest W. Roberts, whose term as a Representative had expired.

RESOLUTION RELATIVE TO INCOME AND EXPENDITURE.

Judge Gray, chairman of the executive committee, submitted the following resolution, which was adopted:

Resolved, That the income of the Institution for the fiscal year ending June 30, 1920, be appropriated for the service of the Institution to be expended by the secretary with the advice of the executive committee, with full discretion on the part of the secretary as to items.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

Judge Gray, chairman, presented the annual report of the committee, showing the financial condition of the Institution for the fiscal year ending June 30, 1918.

On motion, the report was adopted.

ANNUAL REPORT OF THE PERMANENT COMMITTEE.

At the request of Judge Gray, chairman, the secretary presented the following report:

DECEMBER 12, 1918.

To the Board of Regents of the Smithsonian Institution.

GENTLEMEN: Your permanent committee submits herewith its report for the past year on the matters under its supervision:

Hodgkins fund.—As stated in the report made at the last annual meeting \$5,000 per annum for three years had been allotted from the Hodgkins fund to Dr. Charles G. Abbot, Director of the Astrophysical Observatory, for the establishment of a solar radiation observing station in the Argentine Republic, which project had to be temporarily abandoned owing to war conditions. The station was located at Elk Park, N. C., however, and observations taken until the early summer, when the work at that point ceased.

In June, 1918, the observer and his assistant proceeded to Chile and established a station at Calama, 7,500 feet above sea level.

An allotment of \$5,000 from the Hodgkins fund was also made to Mr. R. H. Goddard, of Clark College, for developing certain devices to be used in connection with the study of the temperature of the higher atmospheric strata. This work became merged into a series of important experiments in connection with the work of the War Department.

Avery bequest.—Since the last report two of the properties coming to the Institution under this bequest have been disposed of—No. 120 B Street, NE., and No. 326 A Street, SE. Only one lot remains, situated at No. 140 East Capitol Street. The Avery fund now totals \$28,374.51.

The Bruce Hughes bequest.—The Rev. Bruce Hughes, of Lebanon, Pa., by will dated November 24, 1914, provided in the ninth section that the balance and residue of his estate should come to the Smithsonian Institution, the income to be used for the founding of the Hughes Alcove of the Institution. Mr. Hughes died March 20, 1916, and during the past year the sum of \$9,503.18 has been received from his executors.

The Poore bequest.—As previously stated, \$24,534.82 have been received by the Institution as the proceeds of this estate, exclusive of a number of lots situated in a rather undesirable section of Lowell, Mass. Several attempts have been made to dispose of these properties, but up to this time only one lot has been sold, and deposits have been made on four others. Including the sale mentioned, and additions by earnings to date, this bequest now amounts to \$28,786.98.

Freer Art Gallery.—The present condition of the Freer Art Gallery fund is as follows:

Receipts	\$1, 320, 228. 77
Disbursements	\$703, 662. 36
Balance	616, 566. 41
	<hr/> 1, 320, 228. 77

Consolidated fund.—The consolidated fund of the Institution, which embraces investments in excess of the permanent fund of \$1,000,000 deposited in the Treasury of the United States, now amounts to \$68,974.38.

On motion, the report was approved.

ANNUAL REPORT OF THE SECRETARY.

The secretary presented his report of the operations of the Institution for the year ending June 30, 1918, which was accepted.

REPORT OF THE COMMITTEE ON THE USE OF THE MUSEUM BUILDINGS.

The report of the chairman of the committee, Mr. Henry White, was presented by the secretary, as follows:

NOVEMBER 29, 1918.

To the Board of Regents of the Smithsonian Institution.

GENTLEMEN: I submit herewith my report as chairman of the committee on the use of the museum buildings by the departments of the Government, which was created by resolution of the board of regents, adopted at the annual meeting of the board on December 13, 1917, as follows:

Resolved, That there shall be a committee of the board of regents on the use of the National Museum buildings by the departments of the Government, and the erection of structures on the Smithsonian grounds, which committee shall act for the board with full power on all matters comprehended by this resolution.

Resolved, That such committee shall be appointed by the chancellor, who shall be ex officio a member thereof.

The chancellor appointed the following as members of the committee: Mr. Henry White, the chancellor, Senator Lodge, Senator Stone, Representative Ferris, Mr. Henderson; the secretary of the Institution to act as secretary of the committee.

The immediate occasion for the creation of the committee was the request of the President that certain portions of the new building for the National Museum be allotted to the Bureau of War Risk Insurance for administrative and office purposes. Prior to the meeting of the board, some 25,000 square feet of space had been assigned to this purpose by the secretary, whose action was ratified by the board.

As urgent requests had been received for additional space, this committee was charged with the duty of examining into the matter and of deciding upon the action to be taken.

The committee was convinced that no obstacle should be placed in the way of the proper conduct of the important work of the bureau, whose function is to provide insurance and indemnity for the enlisted men of the Army and Navy; and so at meetings held from time to time additional space was allotted until at the close of the fiscal year, June 30, 1918, the bureau occupied 69,286 square feet, thus providing accommodations for over 3,000 employees of the bureau.

The need for space continued to grow, and the President, on July 5, requested that the building be closed to the public and that all remaining exhibition space be placed at the disposal of the bureau. This was done, thereby making available for the use of the bureau in the basement, or ground floor, and in the two exhibition floors, a total of 133,600 square feet, accommodating between 5,000 and 6,000 of the bureau employees. Much of the expense incident to the adaptation of this space to the purposes of office and administrative work was borne by the bureau.

In view of the action described above, the committee authorized the secretary to open to the public on Sunday afternoons, if considered desirable,

the exhibition portions of the Smithsonian Building and the Industrial Arts Building of the Museum.

It is with regret that I record the death of a member of the committee, Senator Stone, which occurred April 14, 1918. Upon learning that Senator Thomas had been appointed as a regent to succeed him, I invited the latter to take Senator Stone's place upon the committee.

Respectfully submitted.

HENRY WHITE, *Chairman.*

On motion, the report was accepted.

DEATH OF ASSISTANT SECRETARY RICHARD RATHBUN.

The secretary announced the death on July 16, 1918, of Dr. Richard Rathbun, assistant secretary of the Institution.

A statement giving an account of Dr. Rathbun's work and association with the Institution will be found in the annual report of the secretary.

APPOINTMENT OF ADMINISTRATIVE ASSISTANT IN CHARGE OF NATIONAL MUSEUM.

The secretary announced that he had appointed Mr. William de C. Ravenel as administrative assistant to the secretary in charge of the National Museum.

Mr. Ravenel had been associated with the Museum since 1902 as administrative assistant to Dr. Rathbun. He has had unusual museum training and experience, both in connection with his duties and with all governmental expositions held since 1892, and he has been largely instrumental in building up the War Museum which is now assuming importance.

Mr. Ravenel has also been practically in charge of the Arts and Industries Museum for some time, and, in view of this, he has also been appointed to direct its activities.

APPOINTMENT OF ASSISTANT SECRETARY.

The secretary called the attention of the board to the desirability of appointing an assistant secretary, and stated that he had selected Dr. Charles Greeley Abbot, the Director of the Astrophysical Observatory of the Institution.

Dr. Abbot was appointed an assistant to Secretary Langley in 1895 as aid acting in charge of the Astrophysical Observatory. He was engaged continuously in original researches on solar radiation, in cooperation with Mr. Langley up to the time of the latter's death, in 1906, when he assumed the entire charge of that work.

Dr. Abbot is an astronomer, a mathematician, and a physicist, and is forceful, energetic, and effective. He will remain in charge of

the Astrophysical Observatory, and will also take general direction of the library and international exchanges, and perform such other duties as may be assigned to him.

On motion, the appointment of Dr. Abbot as assistant secretary of the Smithsonian Institution was approved.

THE SECRETARY'S SUPPLEMENTAL REPORT.

The secretary made the following statement of results which have been accomplished in the various activities of the institution since the preparation of his annual report:

UNITED STATES NATIONAL MUSEUM.

Additions to collections.—The noteworthy additions to the regular collections of the Museum since July 1, included:

A large collection of historical theatrical costumes, presented by Mrs. Richard Mansfield, consisting of costumes and accessories worn by the late Richard Mansfield.

A priceless collection of antillean land mollusks, about 30,000 lots, approximately 400,000 specimens, donated by a regent of the institution, Mr. John B. Henderson.

Mineral technology.—The collections in this division are being assembled with the two fold purpose of arousing a fuller appreciation of the public's indebtedness to mining and metallurgical enterprises and of promoting a readier familiarity with the production and uses developed. At the beginning of the year 18 groups were on display in the exhibition halls. Besides these exhibits there have been issued during the past 18 months, largely as war contributions, 6 nontechnical pamphlets, as follows:

Coal Products: An object lesson in resource administration.

Fertilizers: An interpretation of the situation in the United States.

Sulphur: An example of industrial independence.

Coal: The resource and its full utilization.

Power: Its significance and needs.

Petroleum: A resource interpretation.

Textiles.—The purposes of the Division of Textiles are to show the raw materials used in the textile arts and the development and use of these from the technical standpoint.

Wood technology illustrates the forests, their products, and the lessons taught by the recent progress in forestry studies.

The Division of Medicine illustrates the evolution of the healing art and the theories of disease; the materials used in medication and various methods of preparing and administering the same; the principles of disease prevention and the materials and appliances used to this end.

In the conservation of food and the selection of a balanced ration, besides attractive instructive exhibits, a diet kitchen, recently opened in conjunction with the Department of Agriculture, furnishes a graphic demonstration of the best and most economic methods of preparing food.

Mechanical technology.—The science which treats of the application of the forces of nature to human needs by means of machinery. This division contains illustrations of the history of transportation by land, sea, and air; the history and development of electricity; weapons of war and of the chase; fishing apparatus; and miscellaneous machinery showing progress in mechanical invention.

Graphic arts.—The division covers the methods and results of printing and binding, besides artistic reproduction by all known methods. In the Section of Photography there is shown by methods, apparatus, and prints a history of photography which is wholly unique.

Musical instruments.—This section contains a collection of musical instruments, both from aboriginal and civilized peoples, exceeded by only one other museum collection in the country, and during the past four years has received a remarkable addition relating to the history of the pianoforte from the earliest times to about 1850.

Ceramics.—This section, through lack of means and space, has only the beginnings of collections of pottery, glass, metal work, etc.

Freer Gallery of Art.—In the last report it was stated that foundations had been laid for a granite structure on the Smithsonian reservation to house the Charles L. Freer collection. Though some delays were encountered in procuring material and labor, the construction of this building has progressed during the year as rapidly as could be expected.

During the year Mr. Freer increased his collections by 928 additions, of which 20 are paintings by the American artists, Whistler, Tryon, Dewing, Melchers, Metcalf, Sargeant, and Brush; while the oriental objects, numbering 908, consist of paintings, pottery, fabrics, jewelry, and objects of jade, bronze, wood, stone, glass, and lacquer. The collection now numbers 6,200 items.

National Gallery of Art.—Among the most recent accessions to the gallery may be mentioned a collection of 12 paintings, 12 miniatures, 9 ivory carvings, a Limoges enamel, a marble bust, a bronze statue, and 140 miscellaneous objects, received by bequest of Mrs. Mary Houston Eddy, of Washington; to be known as "The A. R. and H. M. Eddy Donation."

In addition to many other objects of art, there was also received a series of architectural drawings by Charles Mason Remey, being preliminary designs showing various treatments in different styles of

architecture of the proposed Bahai Temple for Chicago, exhibited during March, 1918.

The natural history building, under normal conditions, is greatly overcrowded with the collections of its departments of biology, geology, and anthropology, and of the art gallery, nearly one-fourth of its space being given over to art in its various forms. The need of considering the erection of a building exclusively for the National Gallery of Art is pressing and should receive early attention. The gallery has already failed to acquire many rich gifts of art works because of the impossibility of caring for them in the present buildings, and because of this unpreparedness art treasures of great worth, well within its reach, have gone elsewhere.

Death of William T. Evans.—In this connection, I regret to announce the death, on November 25, 1918, at Glen Ridge, N. J., of Mr. William T. Evans, whose generous gifts to the National Gallery of Art have been reported.

In 1907, when the project of a national gallery of art had been definitely launched, Mr. Evans was among the first to recognize its importance, and in that year gave 54 paintings, representing the best of American artists. Since then he has added to his gift from time to time until at present his collection numbers 150 paintings, 115 wood engravings, and 1 fine etching, which are valued at approximately \$1,000,000.

War activities.—During the trying conditions that have prevailed in the United States since it entered the war the National Museum has demonstrated its value as a national asset in many ways. Members of its staff of experts, its great collections, its laboratories, and all the information in its possession have been placed unreservedly at the service of the executive departments and other Government agencies, and have been frequently used by a number of them. Its exhibition halls have been closed to visitors and turned into office quarters for over 5,000 employees of one of the important war bureaus of the Government—the Bureau of War Risk Insurance. Facilities for the comfort and recreation of officers and men stationed in the vicinity and drilling on the Mall have been provided in the Smithsonian Building, and the reading rooms of the libraries have been equipped with tables and writing materials for all men in uniform. The Department of Geology has been frequently called upon to furnish materials for experimental work. A single call embraced 27 varieties of minerals. At the request of the National Research Council, the head curator of this department has taken over the entire work of securing optical quartz for the needs of the United States and Great Britain.

The Division of Mineral Technology has concentrated its activities for the year upon the interrelationships and consequent interpend-

ence existing in the industries sustained by mineral resources. In addition to instructive exhibits the curator and his assistants have furnished a large amount of information, including suggestions for insuring a sustained source of oil, and for the systematic assemblage of industrial data as a basis for reconstructional work in man power.

The Division of Physical Anthropology has furnished information on racial questions, particularly relating to the Balkans.

The curator of the Division of Textiles, having charge of food and animal products, cooperated with the Food Administration in planning graphic exhibits for use throughout the country on the subject of conservation. He was also appointed exhibits director in the District of Columbia and served as chairman of the campaign committee to carry out food conservation in the District. Incidentally he has prepared and placed on exhibition in the National Museum an instructive exhibit of foods. Information was also furnished by him to the United States Shipping Board on raw commodities, and assistance in working out a system for classifying commercial data on vegetable fats and oils.

Other geological and biological problems arising in gas warfare, peat investigations, questions in connection with the construction of concrete ships and similar problems were also undertaken. As an illustration of the character of the work done by our experts, the curator of marine invertebrates demonstrated that the ordinary garden slug (which is abundant in Europe) possessed ideal qualifications for detecting poisonous gases, which information was cabled to our Army and the Allies. He also assisted in securing satisfactory fillers for gas filters.

The Museum photographer has rendered valuable assistance in connection with the organization of laboratories in the War and Navy Departments and also in confidential matters.

Since the war commenced 26 employees of the Museum have been granted furloughs to enter the military and naval service of the country.

War Museum.—The Smithsonian Institution, through the Museum administration and with the aid and cooperation of other Government departments, is undertaking to assemble, for permanent exhibition and preservation for the benefit of the public, a series of objects graphically illustrating the military and naval activities of the countries engaged in the present great war. This collection, when completed, will constitute an invaluable historical record of the war as shown by objects connected directly with the conflict, and, in addition to the military and naval features of the struggle, will represent certain economic phases of the war as well.

The collection will consist principally of the classes described below, which will, however, be expanded to cover other classes of matter as the collection develops. The material described under the first 10 headings pertains exclusively to the United States.

(1) Military and naval decorations and medals, including types of all military decorations, medals, and badges awarded by the Government to officers and enlisted men of the Army and Navy for service prior to and during the progress of the conflict.

(2) Military-service insignia, including all types of devices and designs showing the different ranks and branches of the military service.

(3) Individual military equipment, including the equipment of the individual enlisted man of the various branches of the military service, such as clothing, arms, and other paraphernalia.

(4) General military equipment, including machine guns and other objects intrusted to the military squads and organizations rather than to individual soldiers. This class of material includes other objects relating to the air service, such as airplanes of all types, and accessories.

(5) Naval-service insignia, including types of all devices showing the various ranks and branches of the naval service.

(6) Individual naval equipment, including the clothing and equipment furnished to the individual enlisted man of the Navy.

(7) General naval equipment, including models of ships, naval guns, and types of other war paraphernalia employed by the Navy.

(8) Mementoes of persons, including relics of noted individuals serving with the Army or the Navy or otherwise identified with the war activities.

(9) Mementoes of events, including relics of events of special note occurring during the war.

(10) Pictorial and library material, including pictures, maps, books, pamphlets, and other objects of the same character relating to the progress of the war. A nearly complete series of all Liberty loan posters is already in the possession of the Museum, and a complete set of the posters issued by the Navy Department has been promised by that department.

(11) Allied war material, including matters relating to all the classes of material described above as pertaining to the United States.

(12) Enemy countries' war material, including material relating to all of the first 10 classes of material described above as pertaining to the United States.

The initial installation of the war material already received has been made in a suitable section of the Museum amid dignified and proper surroundings, with an adequate allowance of space and in appropriate cases.

BUREAU OF AMERICAN ETHNOLOGY.

Field work.—One of the most important results of field work by the Bureau of American Ethnology during the past year was the investigation of little-known prehistoric towers, castles, and great houses in southwestern Colorado. In conjunction with the Department of the Interior, the Smithsonian Institution has been engaged for a decade in the excavation and repair of large ruins situated on the Mesa Verde National Park. The educational value of this work can hardly be overestimated, and the records show that in the last few years about 2,500 persons visited the locality annually to see these remains of prehistoric ruins in our Southwestern States.

In his field work last summer Dr. J. Walter Fewkes, Chief of the Bureau of American Ethnology, investigated equally instructive groups of ruins in the valleys in the neighborhood of the Mesa Verde Park and found there many well-preserved buildings of which little has hitherto been known.

NATIONAL ZOOLOGICAL PARK.

Attendance record.—The attendance at the park for the year ending June 30, 1918, exceeded all previous records, reaching a total of 1,593,227—a daily average of 4,365. This total is 436,117 over that of 1916, the record year up to this time.

Recent accessions.—The first specimens of the Florida bear (*Ursus floridanus*) ever shown in the park were received August 21. Other accessions of importance are a fine capybara, the largest of existing rodents, from the delta of the Orinoco River, Venezuela; a pair of American prong-horned antelopes received in exchange; and a pair of Philippine water buffaloes.

The secretary added that as an evidence of the good feeling for the United States felt by the Canadians, some fine specimens of Canadian mountain sheep had been sent to the park. He spoke also of efforts being made to secure specimens of the young Sumatran elephant.

ASTROPHYSICAL OBSERVATORY.

Solar eclipse expedition.—Messrs. L. B. Aldrich and Andrew Kramer, assisted by a volunteer, the Rev. Clarence Woodman, C. S. P., of Berkeley, Calif., observed the total solar eclipse of June 8, 1918, at Lakin, Kans. The entire program, including observations of times of contact, photography of the solar corona, and measurements of the brightness of the sky throughout the afternoon and evening, was successfully carried out.

Mount Wilson expedition.—Mr. Aldrich continued the usual observations on Mount Wilson, Calif. In addition, in cooperation with the Army balloon school at Arcadia, Calif., he made novel measure-

ments of cloud reflection by aid of the pyranometer. A military balloon was sent up through the layer of cloud to about 2,800 feet, and over 100 determinations were made. The results were compared with direct measurements of the intensity of total sun and sky radiation shining down from above and showed that 78 per cent of the radiation falling upon a sheet of cloud is reflected back toward space.

Chilean expedition.—In June the Hodgkins fund solar expedition, under A. F. Moore, director, with L. H. Abbot as assistant, reached station at Calama, Chile, 7,500 feet high, on the eastern edge of the nitrate desert, believed to be the most cloudless region in the world. The expedition is equipped in the best possible manner to observe the variations of the sun, and its purpose is to observe the solar changes daily (if possible) for several years, thus acquiring a secure basis for studying the possibility of weather forecasting by aid of solar work.

War activities.—Dr. Abbot was authorized by the secretary soon after war was declared by the United States to consider himself free to aid in the fullest degree in war work without further consultation. During this time he has been almost solely engaged in war investigations, several of which have led to valuable results, and some of which are still in progress.

EXPEDITIONS.

Celebes expedition.—During the past year Mr. H. C. Raven has continued his work in Celebes under the auspices of Dr. W. L. Abbott, whose generosity in providing for this and the Borneo expeditions has been frequently acknowledged. Although this work was interrupted by Mr. Raven's return to America to join the Army, it resulted in the bringing together of nearly 2,000 birds and mammals, together with an important collection of ethnological material. The area explored lies in the central, less-known part of the island. Among the noteworthy mammals obtained are the Anos, or dwarf buffalo, peculiar to the island and not hitherto represented in the National Museum by a wild-killed specimen, and a very remarkable fruit bat previously known from a single specimen taken in the Philippines.

Collins-Garner Kongo expedition.—War conditions have immobilized this expedition in the Fernan Vas region. Our representative, Mr. C. R. W. Aschemeier, however, has been active and successful. He has made numerous shipments of specimens, some of which have not yet arrived. Among his important captures may be mentioned an elephant, a gorilla, several chimpanzees, and numerous buffaloes and antelopes, all representing West African forms practically or entirely new to the Museum.

GENERAL APPENDIX
TO THE
SMITHSONIAN REPORT FOR 1919

ADVERTISEMENT.

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution, from a very early date, to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and this purpose has, during the greater part of its history, been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880 the Secretary, induced in part by the discontinuance of an annual summary of progress which for 30 years previous had been issued by well-known private publishing firms, had prepared by competent collaborators a series of abstracts, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1919.

MODERN THEORIES OF THE SPIRAL NEBULAE.¹

By HEEER D. CURTIS,
Director, Allegheny Observatory.

In one sense that theory of the spiral nebulae to which many lines of recently obtained evidence are pointing can not be said to be a modern theory. There are few modern concepts which have not been explicitly or implicitly put forward as hypotheses or suggestions long before they were actually substantiated by evidence.

The history of scientific discovery affords many instances where men with some strange gift of intuition have looked ahead from meager data, and have glimpsed or guessed truths which have been fully verified only after the lapse of decades or centuries. Herschel was such a fortunate genius. From the proper motions of a very few stars he determined the direction of the sun's movement nearly as accurately, due to a very happy selection of stars for the purpose, as far more elaborate modern investigations. He noticed that the star clusters which appeared nebulous in texture in smaller telescopes and with lower powers, were resolved into stars with larger instruments and higher powers. From this he argued that all the nebulae could be resolved into stars by the application of sufficient magnifying power, and that the nebulae were, in effect, separate universes, a theory which had been earlier suggested on purely hypothetical or philosophical grounds by Wright, Lambert, and Kant. From their appearance in the telescope he, again with almost uncanny prescience, excepted a few as definitely gaseous and irresolvable.

This view held sway for many years; then came the results of spectroscopic analysis, showing that many nebulae (those which we now classify as diffuse or planetary) are of gaseous constitution and can not be resolved into stars. The spiral nebulae, although showing a different type of spectrum, were in most theories tacitly included with the known gaseous nebulae.

¹ Abstract of a lecture given on Mar. 15, 1919, at a joint meeting of the Washington Academy of Sciences and the Philosophical Society of Washington. The lecture was illustrated with numerous lantern slides. Reprinted by permission from the Journal of the Washington Academy of Sciences, vol. 9, No. 8, Apr. 19, 1919.

We have now, as far as the spiral nebulae are concerned, come back to the standpoint of Herschel's fortunate, though not fully warranted deduction, and the theory to which much recent evidence is pointing, is that these beautiful objects are separate galaxies, or "island universes," to employ the expressive and appropriate phrase coined by Humboldt.

By means of direct observations on the nearer and brighter stars, and by the application of statistical methods to large groups of the fainter or more remote stars, the galaxy of stars which forms our own stellar universe is believed to comprise perhaps a billion suns. Our sun, a relatively inconspicuous unit, is situated near the center of figure of this galaxy. This galaxy is not even approximately spherical in contour, but shaped like a lens or thin watch; the actual dimensions are highly uncertain; Newcomb's estimate that this galactic disk is about 3,000 light-years in thickness and 30,000 light-years in diameter is perhaps as reliable as any other.

Of the three classes of nebulae observed, two, the diffuse nebulosities and the planetary nebulae, are typically a galactic phenomenon as regards their apparent distribution in space, and are rarely found at any distance from the plane of our Milky Way. With the exception of certain diffuse nebulosities, whose light is apparently a reflection phenomenon from bright stars involved within the nebulae, both these types are of gaseous constitution, showing a characteristic bright-line spectrum.

Differing radically from the galactic gaseous nebulae in form and distribution, we find a very large number of nebulae predominantly spiral in structure. The following salient points must be taken into account in any adequate theory of the spiral nebulae.

1. In apparent size the spirals range from minute flecks, just distinguishable on the photographic plate, to enormous spirals like Messier 33 and the great nebula in Andromeda, the latter of which covers an area four times greater than that subtended by the full moon.

2. Prior to the application of photographic methods, fewer than 10,000 nebulae of all classes had been observed visually. One of the first results deduced by Director Keeler from the program of nebular photography which he inaugurated with the Crossley reflector at Lick Observatory, was the fact that great numbers of small spirals are within reach of modern powerful reflecting telescopes. He estimated their total number as 120,000 early in the course of this program, and before plates of many regions were available. I have recently made a count of the small nebulae on all available regions taken at the Lick Observatory during the past 20 years² and

² Curtis, H. D., On the number of spiral nebulae, *Proc. Amer. Phil. Soc.* 57: 513. 1918.

from these counts estimate that there are at least 700,000 spiral nebulae accessible with large reflectors.

3. The most anomalous and inexplicable feature of the spiral nebulae is found in their peculiar distribution. They show an apparent abhorrence for our galaxy of stars, being found in greatest numbers around the poles of our galaxy. In my counts I found an approximate density of distribution as follows:

Galactic latitude $\mp 45^\circ$ to $\mp 90^\circ$ -----	34 per square degree.
Galactic latitude -45° to -90° -----	28 per square degree.
Galactic latitude $\mp 30^\circ$ to $\mp 45^\circ$ and -30° to -45° -----	24 per square degree.
Galactic latitude -30° to $\mp 30^\circ$ -----	7 per square degree.

No spiral has as yet been found actually within the structure of the Milky Way. We have doubled and trebled our exposures in regions near the galactic plane in the hope of finding fainter spirals in such areas, but thus far without results. The outstanding feature of the space distribution of the spirals is, then, that they are found in greatest profusion where the stars are fewest, and do not occur where the stars are most numerous. This distribution may be illustrated graphically as follows:

THE FACTOR OF SPACE DISTRIBUTION.

400,000 \pm Spiral nebulae

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Our own stellar universe

is shaped like a thin lens, and is perhaps

3,000 by 30,000 light-years in extent. In this

space occur nearly all the stars, nearly all the new stars, nearly

all the variable stars, most of the diffuse and

planetary nebulae, etc., but *no spiral*

nebulae.

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300,000 \pm Spiral nebulae.

4. The spectrum of the spirals is practically the same as that given by a star cluster, showing a continuous spectrum broken by absorption lines. A few spirals show bright-line spectra in addition.

5. The space-velocities of the various classes of celestial objects are summarized in the following short table:

THE FACTOR OF SPACE VELOCITY.

1. The diffuse nebulae.

Velocities low.

2. The stars.

Velocities vary with spectral type.

Class B stars: Average speeds 8 miles per second.

Class A stars: Average speeds 14 miles per second.

Class F stars: Average speeds 18 miles per second.

Class G stars: Average speeds 19 miles per second.

Class K stars: Average speeds 21 miles per second.

Class M stars: Average speeds 21 miles per second.

3. The star clusters.

Velocities about 100 miles per second.

4. The planetary nebulae.

Average speeds 48 miles per second.

5. The spiral nebulae.

Average speeds 480 miles per second.

The peculiar variation of the space velocity of the stars with spectral type may ultimately prove to be a function of relative mass. The radial velocities of but few spirals have been determined to date; future work may change the value given, but it seems certain that it will remain very high.

It will be seen at once that, with regard to this important criterion of space velocity, the spiral nebulae are very distinctly in a class apart. It seems impossible to place them at any point in a coherent scheme of stellar evolution. We can not bridge the gap involved in postulating bodies of such enormous space velocities either as a point of stellar origin, or as a final evolution product.

On the older theory that the spirals are a part of our own galaxy, it is impossible to harmonize certain features of the data thus far presented. If this theory is true, their grouping near the galactic poles, inasmuch as all evidence points to a flattened or disk form for our galaxy, would indicate that they are relatively close to us. In that event, we should inevitably have detected in this class of objects proper motions of the same order of magnitude as those found for the stars at corresponding distances. Such proper motions are the more to be expected in view of the fact that the average space velocity of the spirals is about 30 times that of the stars. I have repeated all the

earlier plates of the Keeler nebular program, and was able to find no certain evidence of either translation or rotation in these objects in an average time interval of 13 years.³ Their form, and the evidence of the spectroscope, indicate, however, that they are in rotation. Knowing that their space velocities are high, the failure to detect any certain evidence of cross motion is an indication that these objects must be very remote.

Even if the spiral is not a stage in stellar evolution, but a class apart, is it still possible to assume that they are, notwithstanding, an integral part of our own stellar universe, sporadic manifestations of an unknown line of evolutionary development, driven off in some mysterious manner from the regions of greatest star density?

A relationship between two classes of objects may be one of avoidance just as logically as one of contiguity. It has been argued that the absolute avoidance which the spirals manifest for the galaxy of the stars shows incontrovertibly that they must, by reason of this very relationship of avoidance, be an integral feature of our galaxy. This argument has proved irresistible to many, among others to so keen a thinker as Herbert Spencer, who wrote:

In that zone of celestial space where stars are excessively abundant nebulae are rare; while in the two opposite celestial spaces that are furthest removed from this zone nebulae are abundant * * *. Can this be mere coincidence? When to the fact that the general mass of the nebulae are antithetical in position to the general mass of the stars, we add the fact that local regions of nebulae are regions where stars are scarce * * * does not the proof of a physical connection become overwhelming?

It must be admitted that a distribution, which has placed three-quarters of a million objects around the poles of our galaxy, would be against all probability for a class of objects which would be expected to be arranged at random, unless it can be shown that this peculiar grouping is only apparent, and due to some phenomenon in our own galaxy. This point will be reverted to later.

It has been shown that the factors of space velocity and space distribution separate the spirals very clearly from the stars of our galaxy; from these facts alone and from the evidence of the spectroscope the island-universe theory is given a certain measure of credibility.

Another line of evidence has been developed within the past two years which adds further support to the island-universe theory of the spiral nebulae.

³ Curtis, H. D. The proper motion of the nebulae, *Publ. Astron. Soc. Pacific* 27: 214. 1915.

NEW STARS.

Within historical times some 27 new stars have suddenly flashed out in the heavens. Some have been of interest only to the astronomer; others, like that of last June, have rivaled Sirius in brilliancy. All have shown the same general history, suddenly increasing in light ten thousandfold or more, and then gradually, but still relatively rapidly, sinking into obscurity again. They are a very interesting class, nor has astronomy as yet been able to give any universally accepted explanation of these anomalous objects. Two of these novae had appeared in spiral nebulae, but this fact had not been weighed at its true value. Within the past two years over a dozen novae have been found in spiral nebulae, all of them very faint, ranging from about the fourteenth to the nineteenth magnitudes at maximum. Their life history, so far as we can tell from such faint objects, appears to be identical with that of the brighter novae. Now, the brighter novae of the past—that is, those which have not appeared in spirals—have almost invariably been a galactic phenomenon, located in or close to our Milky Way, and they have very evidently been a part of our own stellar system. The cogency of the argument will, I think, be apparent to all, although the strong analogy is by no means a rigid proof. If 27 novae have appeared in our own galaxy within the past 300 years, and if about half that number are found within a few years in spiral nebulae far removed from the galactic plane, the presumption that these spirals are themselves galaxies composed of hundreds of millions of stars is a very probable one.

If, moreover, we make the reasonable assumption that the new stars in the spirals and the new stars in our own galaxy average about the same in size, mass, and absolute brightness, we can form a very good estimate of the probable distance of the spiral nebulae, regarded as island universes. Our galactic novae have averaged about the fifth magnitude. The new stars which have appeared in the spiral nebulae have averaged about the fifteenth magnitude, but it would appear probable that we must inevitably miss the fainter novae in such distant galaxies, and it is perhaps reasonable to assume that the average magnitude of the novae in spirals may be about the eighteenth, or 13 magnitudes fainter than those in our own galaxy. They would thus be about one hundred and sixty thousand times fainter than our galactic novae, and on the assumption that both types of novae average the same in mass, absolute luminosity, etc., the novae in spirals should be four hundred times farther away. We do not know the average distance of the new stars which have appeared in our own galaxy, but 10,000 light-years is perhaps a reasonable esti-

mate.⁴ This would indicate a distance of the order of 4,000,000 light-years for the spiral nebulae. This is an enormous distance, but if these objects are galaxies like our own stellar system, such a distance accords well with their apparent dimensions. Our own galaxy at a distance of 10,000,000 light-years would be about 10 minutes of arc in diameter, or the size of the larger spiral nebulae.

On such a theory a spiral structure for our own galaxy would be probable. Its proportions accord well with the degree of flattening observed in the majority of the spirals. We have very little actual evidence as to a spiral structure for our galaxy; the position of our sun relatively close to the center of figure of the galaxy and our ignorance of the distances of the remoter stars renders such evidence very difficult to obtain. A careful study of the configurations and star densities in the Milky Way has led Professor Easton, of Amsterdam, to postulate a spiral structure for our galaxy.

⁴ *Note added in June, 1920.*—The estimate given above of 10,000 light-years as the average distance of the galactic novae is probably too large. Data obtained since the lecture was delivered now make possible another method of estimating the distance of the spirals, leading, however, to the same general result.

Seventeen novae have appeared in the great nebula of Andromeda, the largest and presumably the closest of the spirals. Sixteen of these were faint, averaging about magnitude 17 at maximum and probably about magnitude 27 at minimum, on the assumption that they vary in this respect as do the galactic novae. The seventeenth, S. Andromedae, was seventh magnitude at maximum, or 10 magnitudes brighter than the average of the fainter novae.

The absolute magnitude, or absolute luminosity, of a star is that apparent magnitude which it would have if seen from the standard distance of 32.6 light-years, and may easily be found from the equation,

Abs. magn.=apparent magn. + $7.6 - 5 \times \text{logarithm of distance}$,

where the distance is expressed in light-years. Converting the apparent magnitudes of the 16 fainter novae into absolute magnitudes on the assumption that this spiral is 500,000 light-years distant, the following comparison may be made with four galactic novae, whose distances, and hence their absolute magnitudes, are known.

	16 novae in Andromeda, if at 500,000 light-years distance.	4 galactic novae of known distance.
Absolute magnitude at maximum.....	-3.9	-3.4
Absolute magnitude at minimum.....	+6.1	+7.2

Though it must be admitted that the data for such a correlation are still very limited, a distance of 500,000 light-years is strongly indicated for the nebula of Andromeda, and, if the spirals are structures of roughly the same order of actual size, a distance of 10,000,000 or more light-years would be expected for the apparently smaller spirals.

At this distance for the nebula in Andromeda, S. Andromedae, evidently an exceptional nova, would have the very great absolute magnitude of -13.9. The "dispersion" of the novae in absolute magnitude is evidently very large, as indicated by the difference of 10 magnitudes between S. Andromedae and the fainter novae in this spiral. An absolute magnitude of -14 does not seem impossible for certain exceptional novae in our own system. Tycho's nova was brighter than Venus at its maximum, and if this nova was as close to us as 1,000 light-years, its absolute magnitude must have been about -13.

DISTRIBUTION OF SPIRALS.

There is still left one outstanding and unexplained problem in the island universe theory or any other theory of the spiral nebulae. Neither theory, as outlined, offers any satisfactory explanation of the remarkable distribution of the spirals. On the older theory, if a feature of our galaxy, what has driven them out to the points most remote from the regions of greatest star density? If, on the other hand, the spirals are island universes, it is against all probability that our own universe should have chanced to be situated about halfway between two great groups of island universes, and that not a single object of the class happens to be located in the plane of our Milky Way.

There is one very common characteristic of the spirals which may be tentatively advanced as an explanation of the peculiar grouping of the spirals.

A very considerable proportion of the spirals show indubitable evidence of occulting matter, lying in the plane of the greatest extension of the spiral, generally outside the whorls, but occasionally between the whorls as well. This outer ring of occulting matter is most easily seen when the spiral is so oriented in space as to turn its edge toward us. But the phenomenon is also seen in spirals whose planes make a small, but appreciable angle with our line of sight, manifesting itself in such appearances as "lanes" more prominent on one side of the major axis of the elongated elliptical projection, in a greater brightness of the nebular matter on one side of this major axis, in a fan-shaped nuclear portion, or in various combinations of these effects. The phenomenon is a very common one. Illustrations of 78 spirals showing evidences of occulting matter in their peripheral equatorial regions, with a more detailed discussion of the forms observed, are now being published,⁵ and additional examples of the phenomenon are constantly being found.

While we have as yet no definite proof of the existence of such a ring of occulting matter lying in our galactic plane and outside of the great mass of the stars of our galaxy, there is a great deal of evidence for such occulting matter in smaller areas in our galaxy. Many such dark areas are observed around certain of the diffuse nebulosities, or seen in projection on the background furnished by such nebulosities or the denser portions of the Milky Way; these appearances seem to be actual "dark nebulae."⁶ The curious "rifts"

⁵ Curtis, H. D., *Occulting effects in spiral nebulae*, Univ. Calif. Semi-Cent. Publ. (in press).

⁶ Barnard, E. E., *On the dark markings of the sky, with a catalogue of 182 such objects*, *Astrophys. Journ.* 49:1, 1919; Curtis, H. D., *Dark nebulae*, *Publ. Astron. Soc. Pacific* 30:65, 1918.

in the Milky Way may well be ascribed, at least in part, to such occulting matter.

Though we thereby run the risk of arguing in a circle, the fact that no spirals can be detected in our galactic plane, a natural result of such a ring of occulting matter, would in itself appear to lend some probability to the hypothesis. The peculiar distribution of the spiral nebulae would then be explained as due, not to an actual asymmetrical and improbable distribution in space, but to a cause within our own galaxy, assumed to be a spiral with a peripheral ring of occulting matter similar to that observed in a large proportion of the spirals. The argument that the spirals must be an integral feature of our own galaxy, based on a relationship of avoidance, would then lose its force. The explanation appears to be a possibility, even a strong probability, on the island universe theory, and I know of no other explanation, on any theory, for the observed phenomenon of nebular distribution about our galactic poles.

SUMMARY.

The spiral nebulae as island universes.

1. On this theory it is unnecessary to attempt to coordinate the tremendous space velocities of the spirals with the thirtyfold smaller values found for the stars. Very high velocities have been found for the Magellanic Clouds, which may possibly be very irregular spirals, relatively close to our galaxy.

2. There is some evidence for a spiral structure in our own galaxy.

3. The spectrum of the majority of the spirals is practically identical with that given by a star cluster; a spectrum of this general type is such as would be expected from a vast congeries of stars.

4. If the spirals are separate universes, similar to our galaxy in extent and in number of component stars, we should observe many new stars in the spirals, closely resembling in their life history the 27 novae which have appeared in our own galaxy. Over a dozen such novae in spirals have been found, and it is probable that a systematic program of repetition of nebular photographs will add greatly to this number. A comparison of the average magnitudes of the novae in spirals with those of our own galaxy indicates a distance of the order of 10,000,000 light-years for the spirals. Our own galaxy at this distance would appear 10' in diameter, the size of the larger spirals.

5. A considerable proportion of the spirals show a peripheral equatorial ring of occulting matter. So many instances of this have been found that it appears to be a general though not universal characteristic of the spirals; the existence of such an outer ring of occult-

ing matter in our own galaxy, regarded as a spiral, would furnish an adequate explanation of the peculiar distribution of the spirals. There is considerable evidence of such occulting matter in our galaxy.

An English physicist has cleverly said that any really good theory brings with it more problems than it removes. It is thus with the island-universe theory. It is impossible to do more than to mention a few of these problems, with no attempt to divine those which may ultimately be presented to us.

While the data are too meager as yet, several attempts have been made to deduce the velocity of our own galaxy within the super-galaxy. It would not be surprising if the space-velocity of our galaxy, like those of the spirals and the Magellanic Clouds, should prove to be very great, hundreds of miles per second.

Further, what are the laws which govern the forms assumed, and under which these spiral whorls are shaped? Are they stable structures; are the component stars moving inward or outward? A beginning has been made by Jeans and other mathematicians on the dynamical problems involved in the structure of the spirals. The field for research is, like our subject matter, practically infinite.



A HALF-TONE REPRODUCTION OF ONE OF THE NEGATIVES TAKEN WITH THE 4-INCH LENS AT SOBRAL.

Thus shows the position of the stars and, as far as possible in a reproduction of this kind, the character of the images, as there has been no retouching.

A DETERMINATION OF THE DEFLECTION OF LIGHT BY THE SUN'S GRAVITATIONAL FIELD, FROM OBSERVATIONS MADE AT THE TOTAL ECLIPSE OF MAY 29, 1919.¹

By Sir F. W. DYSON, F. R. S., *astronomer royal*, Prof. A. S. EDDINGTON, F. R. S.,
and Mr. C. DAVIDSON.

[With 1 plate.]

I. PURPOSE OF THE EXPEDITIONS.

1. The purpose of the expeditions was to determine what effect, if any, is produced by a gravitational field on the path of a ray of light traversing it. Apart from possible surprises, there appeared to be three alternatives, which it was especially desired to discriminate between—

(1) The path is uninfluenced by gravitation.

(2) The energy or mass of light is subject to gravitation in the same way as ordinary matter. If the law of gravitation is strictly the Newtonian law, this leads to an apparent displacement of a star close to the sun's limb amounting to 0.87'' outward.

(3) The course of a ray of light is in accordance with Einstein's generalized relativity theory. This leads to an apparent displacement of a star at the limb amounting to 1.75'' outward.

In either of the last two cases the displacement is inversely proportional to the distance of the star from the sun's center, the displacement under (3) being just double the displacement under (2).

It may be noted that both (2) and (3) agree in supposing that light is subject to gravitation in precisely the same way as ordinary matter. The difference is that, whereas (2) assumes the Newtonian law, (3) assumes Einstein's new law of gravitation. The slight deviation from the Newtonian law, which on Einstein's theory causes

¹ Reprinted by permission from Philosophical Transactions of the Royal Society of London, Series A, vol. 220, pp. 291-333.

an excess motion of perihelion of Mercury, becomes magnified as the speed increases, until for the limiting velocity of light it doubles the curvature of the path.

2. The displacement (2) was first suggested by Professor Einstein¹ in 1911, his argument being based on the principle of equivalence, viz, that a gravitational field is indistinguishable from a spurious field of force produced by an acceleration of the axes of reference. But apart from the validity of the general principle of equivalence there were reasons for expecting that the electromagnetic energy of a beam of light would be subject to gravitation, especially when it was proved that the energy of radioactivity contained in uranium was subject to gravitation. In 1915, however, Einstein found that the general principle of equivalence necessitates a modification of the Newtonian law of gravitation, and that the new law leads to the displacement (3).

3. The only opportunity of observing these possible deflections is afforded by a ray of light from a star passing near the sun. (The maximum deflection by Jupiter is only $0.017''$.) Evidently, the observation must be made during a total eclipse of the sun.

Immediately after Einstein's first suggestion, the matter was taken up by Dr. E. Freundlich, who attempted to collect information from eclipse plates already taken; but he did not secure sufficient material. At ensuing eclipses plans were made by various observers for testing the effect, but they failed through cloud or other causes. After Einstein's second suggestion had appeared, the Lick Observatory expedition attempted to observe the effect at the eclipse of 1918. The final results are not yet published. Some account of a preliminary discussion has been given,² but the eclipse was an unfavorable one, and from the information published the probable accidental error is large, so that the accuracy is insufficient to discriminate between the three alternatives.

4. The results of the observations here described appear to point quite definitely to the third alternative, and confirm Einstein's generalized relativity theory. As is well-known the theory is also confirmed by the motion of the perihelion of Mercury, which exceeds the Newtonian value by $43''$ per century—an amount practically identical with that deduced from Einstein's theory. On the other hand, his theory predicts a displacement to the red of the Fraunhofer lines on the sun amounting to about 0.008 \AA in the violet. According to Doctor St. John³ this displacement is not confirmed. If

¹ *Annalen der Physik*, Vol. XXXV, p. 898.

² *Observatory*, Vol. XLII, p. 298.

³ *Astrophysical Journal*, Vol. XLVI, p. 249.

this disagreement is to be taken as final it necessitates considerable modifications of Einstein's theory, which it is outside our province to discuss. But, whether or not changes are needed in other parts of the theory, it appears now to be established that Einstein's law of gravitation gives the true deviations from the Newtonian law both for the relatively slow-moving planet Mercury and for the fast-moving waves of light.

It seems clear that the effect here found must be attributed to the sun's gravitational field and not, for example, to refraction by coronal matter. In order to produce the observed effect by refraction, the sun must be surrounded by material of refractive index $1 + 0.00000414/r$, where r is the distance from the center in terms of the sun's radius. At a height of one radius above the surface the necessary refractive index 1.00000212 corresponds to that of air at $\frac{1}{140}$ atmosphere, hydrogen at $\frac{1}{60}$ atmosphere, or helium at $\frac{1}{20}$ atmospheric pressure. Clearly a density of this order is out of the question.

II. PREPARATIONS FOR THE EXPEDITIONS.

5. In March, 1917,⁵ it was pointed out as the result of an examination of the photographs taken with the Greenwich astrographic telescope at the eclipse of 1905 that this instrument was suitable for the photography of the field of stars surrounding the sun in a total eclipse. Attention was also drawn to the importance of observing the eclipse of May 29, 1919, as this afforded a specially favorable opportunity owing to the unusual number of bright stars in the field, such as would not occur again for many years.

With weather conditions as good as those at Sfax in the 1905 eclipse—and these were by no means perfect—it was anticipated that 12 stars would be shown. Their positions are indicated in the diagram on page 136, on which is also marked on the same scale the outline of a 16 by 16 centimeter plate (used with the astrographic telescopes of 3.43 meters focal length) and a 10 by 8 inch plate (used with a 4-inch lens of 19 feet focal length).

The following table gives the photographic magnitudes and standard coordinates of the stars, and the gravitational displacements in x and y calculated on the assumption of a radial displacement $1.75'' \frac{r_0}{r}$, where r is the distance from the sun's center and r_0 the radius of the sun.

⁵ Monthly Notices, R. A. S., LXXVII, p. 445.

TABLE I.

No.	Names.	Photog. mag.	Coordinates. Unit=50".		Gravitational displacement.			
					Sobral.		Principe.	
			x.	y.	x.	y.	x.	y.
	Sun's center (Sobral).....	m.	+0.436	-0.263	"	"	"	"
	Sun's center (Principe).....		+0.553	-0.246				
1	B.D., 21°, 641.....	7.0	+0.026	-0.200	-1.31	+0.20	-1.04	+0.09
2	Piazzi, IV, 82.....	5.8	+1.079	-0.328	+0.85	-0.09	+1.02	-0.16
3	κ^2 Tauri.....	5.5	+0.348	+0.360	-0.12	+0.87	-0.28	+0.81
4	κ^1 Tauri.....	4.5	+0.334	+0.472	-0.10	+0.73	-0.21	+0.70
5	Piazzi, IV, 61.....	6.0	-0.160	-1.107	-0.31	-0.43	-0.31	-0.38
6	ν Tauri.....	4.5	+0.587	+1.099	+0.04	+0.40	+0.01	+0.41
7	B.D., 20°, 741.....	7.0	-0.707	-0.864	-0.38	-0.20	-0.35	-0.17
8	B.D., 20°, 740.....	7.0	-0.727	-1.040	-0.33	-0.22	-0.29	-0.20
9	Piazzi, IV, 53.....	7.0	-0.483	-1.303	-0.26	-0.30	-0.26	-0.27
10	72 Tauri.....	5.5	+0.860	+1.321	+0.09	+0.32	+0.07	+0.34
11	66 Tauri.....	5.5	-1.261	-0.160	-0.32	+0.02	-0.30	+0.01
12	53 Tauri.....	5.5	-1.311	-0.918	-0.28	-0.10	-0.26	-0.09
13	B.D., 22°, 688.....	8.0	+0.089	+1.007	-0.17	+0.40	-0.14	+0.39

It may be noted that No. 1 is lost in the corona on the photographs taken at Sobral. The star, No. 13, of magnitude 8.0, is shown on some of the astrographic plates at Sobral.

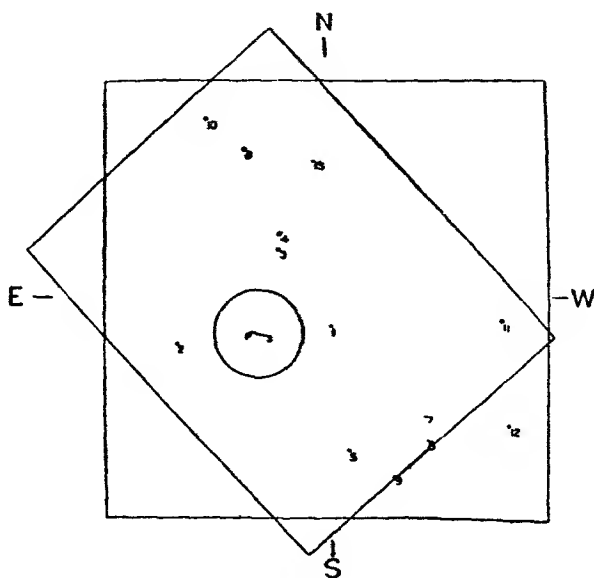


Fig. 1.

6. The track of the eclipse runs from North Brazil across the Atlantic, skirting the African coast near Cape Palmas, passing through the Island of Principe, then across Africa to the western shores of Lake Tanganyika. Inquiry as to the suitable sites and probable weather conditions was kindly made by Mr. Hinks. It appeared that a station in North Brazil, the Island of Principe, and a station on the west of Lake Tanganyika were possible. A station near Cape Palmas did not seem desirable from the meteorological reports though, as the event proved, the eclipse was observed in a cloudless sky by Professor Bauer, who was there on an expedition to observe magnetic effects. At the station at Tanganyika it was thought the sun was at too low an altitude for observations of this character, owing to the large displacements which would be caused by refraction.

A circular received from Doctor Morize, the director of the observatory at Rio, stated that Sobral was the most suitable station in North Brazil and gave copious information of the meteorological conditions, mode of access, etc.

7. Acting on this information the joint permanent eclipse committee at a meeting on November 10, 1917, decided, if possible, to send expeditions to Sobral in North Brazil, and to the Island of Principe. Application was made to the government grant committee for £100 for instruments and £1,000 for the expedition, and a subcommittee consisting of Sir F. W. Dyson, Professor Eddington, Professor Fowler, and Professor Turner was appointed to make arrangements for the expeditions. This subcommittee met in May and June, 1918, and made provisional arrangements for Professor Eddington and Mr. Cottingham to take the object glass of the Oxford astrographic telescope to Principe, and Mr. Davidson and Father Cortie to take the object glass of the Greenwich astrographic telescope to Sobral. It was arranged for the clocks and mechanism of the cœlostats to be overhauled by Mr. Cottingham. Preliminary inquiries were also set on foot as to shipping facilities, from which it appeared very doubtful whether the expeditions could be carried through.

Conditions had changed materially in November, 1918, and at a meeting of the subcommittee on November 8, it was arranged to assemble the instruments at Greenwich, and make necessary arrangements with all speed for the observers to leave England by the end of February, 1919. In addition to the astrographic object glasses fed by 16-inch cœlostats, Father Cortie suggested to the subcommittee the use of the 4-inch telescope of 19-feet focus, which he had used at Hernosand, Sweden, in 1914, in conjunction with an 8-inch cœlostat, the property of the Royal Irish Academy. It was arranged to

ask for the loan of these instruments. As Father Cortie found it impossible to spare the necessary time for the expedition his place was taken by Doctor Crommelin of the Royal Observatory.

8. In November, 1918, the only workman available at the Royal Observatory was the mechanic, the carpenter not having been released from military service. In these circumstances Mr. Bowen, the civil engineer at the Royal Naval College, was consulted. He kindly undertook the construction of frame huts covered with canvas, which could be easily packed and readily put together. These were generally similar to those used in previous expeditions from the Royal Observatory. (See *Monthly Notices*, Vol. LVII., p. 101.) He also lent the services of a joiner who worked at the observatory on the woodwork of the instruments.

It was found possible to obtain steel tubes for the astrographic objectives. These were, for convenience of carriage, made in two sections which could be bolted together. The tubes were provided with flanges at each end, the objective being attached to one of these, and a wooden breech piece to the other. In the breech piece suitable provision was made for the focusing and squaring on of the plates. The plate holders were of a simple construction, permitting the plate to be pushed into contact with three metal tilting screws on the breech piece thus insuring a constancy of focal plane. Eighteen plate-carriers were obtained for each of the astrographic telescopes, made according to a pattern supplied.

With the 4-inch lens Father Cortie lent the square wooden tube used by him in 1914. This was modified at the breech end to secure greater rigidity and constancy of focus.

It was designed for dark slides carrying 10 by 8-inch plates, and four of these, carrying eight plates, were lent with the telescope. The desirability of using larger plates was considered, but the time at disposal to make the necessary alterations was insufficient.

The 16-inch cœlostats which had been overhauled by Mr. Cottingham were mounted and tested as far as the unfavorable weather conditions of February, 1919, would permit. The 8-inch cœlostatt was constructed for these latitudes. To make it serviceable near the equator a strong wooden wedge was made on which the cœlostatt was bolted.

The 8-inch mirror was silvered at the observatory, but owing to lack of facilities for maintaining a uniform temperature approaching 60° F. in the wintry weather of February, the larger mirrors were sent away to be silvered.

Photographic plates, suitably packed in hermetically sealed tin boxes, were obtained from the Ilford and Imperial Cos. The Ilford

plates employed were Special Rapid and Empress, and those of the Imperial Co., Special Sensitive, Sovereign, and Ordinary.

The instruments were carefully packed and sent to Liverpool a week in advance, with the exception of the objectives. These were packed in cases inside hampers and remained under the personal care of the observers, who embarked on the *Anselm* on March 8.

III. THE EXPEDITION TO SOBRAL.

[Observers, Dr. A. C. D. Crommelin and Mr. C. Davidson.]

9. Sobral is the second town of the State of Ceara, in the north of Brazil. Its geographical coordinates are: Longitude 2h. 41m. 25s. west; latitude $3^{\circ} 41' 33''$ south; altitude 230 feet. Its climate is dry and though hot not unhealthy.

The expedition reached Para on the *Anselm* on March 23. There was a choice of proceeding immediately to Sobral or waiting for some weeks. It was considered undesirable to go there before we heard from Doctor Morize what arrangements were being made, so we reported our arrival to him by telegram and decided to await his reply. As we had thus some time on our hands we continued the voyage to Manaos in the *Anselm*, returning to Para on April 8.

By the courtesy of the Brazilian Government our heavy baggage was passed through the customs without examination and we continued our journey to Sobral, leaving Para on April 24 by the steamer *Fortaleza* and arriving at Camocim on April 29. Here we were met by Mr. John Nicolau, who had been instructed to assist us with our baggage through to Sobral. We proceeded from Camocim to Sobral by train on April 30, our baggage following the next day.

We were met at Sobral station by representatives of both the civil and ecclesiastical authorities, headed respectively by Dr. Jacome d'Oliveira, the prefect, and Monsignor Ferreira, and conducted to the house which had been placed at our disposal by the kindness of its owner, Col. Vicente Saboya, the deputy for Sobral. We were joined there nine days later by the Washington (Carnegie) Eclipse Commission, consisting of Messrs. Daniel Wise and Andrew Thomson.

We are greatly indebted to Dr. Leocadio Araujo, of the State Ministry of Agriculture, who had been deputed to interpret for us and to assist us in our preparations. His services were invaluable, and contributed greatly to our success, as also to our well-being during our stay.

10. A convenient site for the eclipse station offered itself just in front of the house; this was the race course of the Jockey Club, and was provided with a covered grand stand, which we found

most convenient for unpacking and storage and in the preparatory work. We laid down a meridian line, after which brick piers were constructed for the cœlostats and for the steel tube of the astrographic telescope. Whilst this was in progress the huts were being erected.

The pier of the small cœlostat was constructed so as to leave a clear space in the middle of one end for the fall of the weight, which was thus below the driving barrel of the clock. By continuing the hole below the foundations of the pier, space was provided for a fall of the weight permitting a run of 25 minutes. In the case of the 16-inch cœlostat, the clock was mounted on the top of a long wooden trunk, nearly 4 feet in length, which was placed on end, and sunk in the earth to a depth of about 2 feet. The weight descended inside the trunk directly from the driving barrel, and had space for a continuous run of over half an hour.

The 16-inch cœlostat had free adjustment for all latitudes; but the 8-inch one, constructed for European latitudes, was mounted on a wooden base, inclined at an angle of about 40° , constructed before leaving Greenwich. The clock had to be separated from the cœlostat, mounted on a wooden base and reversed, to adjust to the Southern Hemisphere. It performed very satisfactorily, and no elongation of the star images is shown with 28 seconds' exposure.

To provide for the changing declination of the sun the piers of the astrographic telescope were made with grooves in the top, in which the wooden V-supports of the tube could slide, thus allowing for the change of azimuth.

The tube of the astrographic telescope was circular in section, and could rest in any position in the V's; for convenience it was adjusted so that the directions of right ascension and declination were parallel to the sides of the plate; this involved a tilt of the plate holders of about 4 degrees to the horizontal.

The 4-inch lens was taken as an auxiliary; we used the square wooden tube, 19 feet in length, originally used by Father Cortie at Hernosand in 1914, together with the 10 by 8 inch plate carriers. Study of the star diagram showed that seven stars could be photographed by turning the plate through 45° . The tube was therefore placed on its angle, large wooden V-supports being prepared to fit the tube; these rested on strong wooden trestles.

The focusing was at first done visually on Arcturus, using an eyepiece fitted with a cobalt glass, after the plate supports and object glass had been adjusted for perpendicularity to the axis. A series of exposures was then made, the focus being varied slightly so as to cover a sufficient range. Examination of these photographs showed at once that there was serious astigmatism due to the figure

of the mirror of the 16-inch cœlostæt. By inserting an 8-inch stop this was reduced to a large extent, and this stop was henceforth used throughout; but the defect was of such a character that it was clear that it would be necessary to stay at Sobral and obtain comparison plates of the eclipse field in July when the sun had moved away.

The focus of the 4-inch was determined in a similar manner. The images, though superior to those of the astrographic, were not quite perfect, and here again comparison plates in July were necessary. Once the focus had been decided on, the breech end was securely screwed up to avoid any chance of subsequent movement.

A few check plates of the field near Arcturus were taken, but have not been used.

11. The following is a summary of the meteorological conditions during our stay. The barometer record was interesting in that it showed very little change from day to day, in spite of changes in the type of weather; there was, however, a very well marked semi-diurnal variation, with range of about 0.15 inch. The temperature range was fairly uniform, from a maximum of about 97° F. toward 3 p. m. to a minimum of about 75° at 5 a. m. The relative humidity (as shown by a hygrograph belonging to the Brazilian Commission) followed the temperature closely, varying from 30 per cent in the afternoon to 90 per cent in the early morning.

May is normally the last month of the rainy season at Sobral, but this year the rainfall was very scanty; there were a few afternoon showers, each ushered in by a violent gust of wind; and on May 25 there was very heavy rain, which was welcome for its moistening effect on the ground, the dust hitherto having been troublesome to the clockwork although every care had been taken to protect it. There was a fair amount of cloud in the mornings, but the afternoons and nights were clear in the majority of cases. Mount Meruoca, 2,700 feet high, about 6 miles to the northwest, was a collector of cloud, its summit being frequently veiled in mist. In spite of its cooler climate, the summit would thus not have been a suitable eclipse station, and, in fact, nothing of the total phase of the eclipse was seen from it.

12. Although water was generally scarce, we were very fortunately situated as we enjoyed an unlimited supply of good water laid on at the house. This was of great benefit in the photographic operations. Ice was unobtainable, but by the use of earthenware water-coolers it was possible to reduce the temperature to about 75°, and by working only at night or before dawn development of the plates was fairly easy. Formalin was used in every case to harden the films, and thereby minimize the chance of distortion due to the softening of the films by the warm solutions.

We had provided ourselves with two brands of plates, but it had become apparent from photographs taken and developed before the eclipse that one of these brands was unsuitable in the hot climate, and it was decided to use practically only one brand of plates.

In taking the experimental photographs it was noticed that the clocks and cœlostats were very sensitive to wind. We had reason to fear strong gusts about the time of totality, such as had occurred in other eclipses; and as the conditions of our locality seemed to render them specially probable, protective wind screens were erected round the hut openings at every point where it was possible without interfering with the field of view. Happily dead calm prevailed at the critical time. Screens also protected all projecting parts of the telescope tubes from direct sunlight.

The performance of the 16-inch cœlostat was unsatisfactory in respect of driving. There was a clearly marked oscillation of the images on the screen in a period of about 30 seconds. For this reason exposure time was shortened, so as to multiply the number of exposures in the hope that some would be near the stationary points.

13. The morning of the eclipse day was rather more cloudy than the average, and the proportion of cloud was estimated at $\frac{2}{10}$ at the time of first contact, when the sun was invisible; it appeared a few seconds later, showing a very small encroachment of the moon, and there were various short intervals of sunshine during the partial phase which enabled us to place the sun's image at its assigned position on the ground glass, and to give a final adjustment to the rates of the driving clocks. As totality approached, the proportion of cloud diminished, and a large clear space reached the sun about one minute before second contact. Warnings were given 58 seconds, 22 seconds, and 12 seconds before second contact by observing the length of the disappearing crescent on the ground glass. When the crescent disappeared the word "go" was called and a metronome was started by Doctor Leocadio, who called out every tenth beat during totality, and the exposure times were recorded in terms of these beats. It beat 320 times in 310 seconds; allowance has been made for this rate in the recorded times. The program arranged was carried out successfully, 19 plates being exposed in the astrographic telescope with alternate exposures of 5 and 10 seconds, and eight in the 4-inch camera, with a uniform exposure of 28 seconds. The region round the sun was free from cloud, except for an interval of about a minute near the middle of totality, when it was veiled by thin cloud, which prevented the photography of stars, though the inner corona remained visible to the eye and the plates exposed at this time show it and the large prominence excellently defined. The plates remained in their holders until development, which was carried out in con-

venient batches during the night hours of the following days, being completed by June 5.

14. No observation of contact times was made, but it is known that these times were somewhat before those calculated. As the times recorded were reckoned from second contact, it is assumed that this occurred May 28, 23 hours 58 minutes 18 seconds Greenwich mean time.

The details of the exposures are given in the following tables:

Exposures with the 13-inch astrographic telescope stopped to 8 inches.

Ref. No.	Greenwich mean time at commencement of exposure.	Exposure.	Plate.	Ref. No.	Greenwich mean time at commencement of exposure.	Exposure.	Plate.
	<i>d. h. m. s.</i>	<i>s.</i>			<i>d. h. m. s.</i>	<i>s.</i>	
1	28 23 58 23	5	O.	11	29 0 1 7	5	S. R.
2		37	E.	12		22	E.
3		57	E.	13		36	E.
4	59 11	10	S.	14		51	S. R.
5		30	S. R.	15	2 10	5	S. R.
6		45	S. R.	16		25	S. R.
7	29 0 0 4	5	S. R.	17		44	E.
8		19	E.	18		58	E.
9		39	E.	19	3 18	5	O.
10		53	S. R.				

Exposures with the 4-inch telescope.

Ref. No.	Greenwich mean time at commencement of exposure.	Exposure.	Plate.	Ref. No.	Greenwich mean time at commencement of exposure.	Exposure.	Plate.
	<i>d. h. m. s.</i>	<i>s.</i>			<i>d. h. m. s.</i>	<i>s.</i>	
1	28 23 58 21	28	S. R.	5	29 0 0 56	28	S. R.
2	59 0	28	S. R.	6	1 34	28	S. R.
3	38	28	S. R.	7	2 13	28	S. R.
4	29 0 0 17	28	S. R.	8	52	28	S. R.

In the fourth column the letter O. stands for Imperial Ordinary, E. stands for Empress, S. stands for Sovereign, S. R. stands for Ilford Special Rapid.

With the astrographic telescope 12 stars are shown on a number of plates, and seven stars on all but three (Nos. 13, 14, and 19). Of the eight plates taken with the 4-inch lens, seven show seven stars, but No. 6, which was taken through cloud, does not show any.

The following table of temperatures, communicated by Doctor Morize, and converted into the Fahrenheit scale, shows how slight the fall was during totality, probably owing to the large amount of cloud in the earlier stages, which checked the usual daily rise.

Greenwich mean time.	Thermometer.	Greenwich mean time.	Thermometer.	Greenwich mean time.	Thermometer.	Greenwich mean time.	Thermometer.
d. h. m.	°	d. h. m.	°	d. h. m.	°	d. h. m.	°
28 22 45	82.4	28 23 30	80.6	29 0 15	82.0	29 1 0	83.8
23 0	84.2	45	82.4	30	82.4	15	84.2
15	82.4	29 0 0	80.6	45	83.1	30	84.2

15. On June 7, having completed the development, we left Sobral for Fortaleza, returning on July 9 for the purpose of securing comparison plates of the eclipse field.

Before our departure we dismounted the mirrors and driving clocks which were brought into the house to avoid the exposure to dust. The telescopes and cœlostats were left in situ. Before removing the mirrors we marked their position in their cells so that they could be replaced in exactly the same position.

After our return to Sobral the mirrors and clocks were remounted; the photography of the eclipse field was commenced on the morning of July 11 (civil). The difficulty of finding the field with the cœlostats was overcome by making a rough hour circle on the heads of the cœlostats out of millimeter paper.

The following is the list of exposures made on the field for comparison with the eclipse photographs:

[The reference numbers follow the civil dates.]

Astrographic telescope.						4-inch telescope.					
Reference number.	Date.	Greenwich mean time.	Number of exposures.	Duration.	Altitude.	Reference number.	Date.	Greenwich mean time.	Number of exposures.	Duration.	Altitude.
		<i>h. m.</i>		<i>s.</i>	°			<i>h. m.</i>		<i>s.</i>	°
11 ₁	July 10	20 5	3	5	28.9	14 ₁	July 13	20 7	2	25	32.4
11 ₂		20 16	2	5	31.1	14 ₂		20 16	2	20	34.3
11 ₃		20 21	1	5	32.2						
14 ₁	July 13	20 13	3	5	33.7	15 ₁	July 14	20 17	2	20	35.4
14 ₂		20 17	2	5	34.5	15 ₂		20 22	2	20	36.4
14 ₃		20 19	2	5	34.9						
15 ₁	July 14	20 15	3	5	34.9	17 ₁	July 16	20 6	3	15	34.7
15 ₂		20 20	2	5	36.1	17 ₂		20 24	2	15	38.6
15 ₃		20 23	2	5	36.6						
17 ₁	July 16	20 2	4	3	33.8						
17 ₂		20 15	3	3	36.6	18 ₁	July 17	19 57	3	20	33.6
17 ₃		20 23	2	3	38.3	18 ₂		20 24	2	20	39.2
17 ₄		20 25	2	5	38.8						
18 ₁	July 17	19 50	3	4	32.8						
18 ₂		20 1	2	4	34.4						
18 ₃		20 20	3	4	38.6						
18 ₄		20 25	2	3	39.5						

¹ The 4-inch plate, No. 18₁, was taken through the glass (see sec. 17, *infra*) to facilitate the measurement and is referred to as the scale plate.

Thermometer readings, July 10, 74.4° ; July 13, 73.7° ; July 14, 71.9° ; July 16, 72.3° ; July 17, 72.3° .

By July 18 we had obtained a sufficient number of reference photographs. Dismantling of the instruments was commenced, and the packing was completed on July 21. We left Sobral on July 22, leaving the packing cases in the hands of Messrs. Nicolau and Carneiro to be forwarded at the earliest opportunity, and arrived at Greenwich on August 25.

The observers wish to record their obligations to Mr. Charles Booth and the officers of the Booth Line for facilitating their journeys to and from their station at a difficult time.

PHOTOGRAPHS TAKEN WITH THE 4-INCH OBJECT GLASS.

16. These photographs were taken on 10 by 8 inch plates. By suitably mounting the camera it was made possible to obtain seven stars on the photographs, viz, Nos. 2, 3, 4, 5, 6, 10, and 11 of the table in section 5. Of the eight photographs taken during the eclipse seven gave measurable images of these stars, the other plate (No. 6) taken through cloud only showing a picture of the prominences.

Plates of the same field taken under nearly similar conditions as regards altitude were taken on July 14, 15, 17, and 18 (civil date). Of these photographs, the second taken on July 14 with two exposures (referred to as 14_{2a} and 14_{2b}), two photographs taken on July 15 (referred to as 15_1 and 15_2), two on July 17 (17_1 and 17_2), and the second photograph on July 18 (18_2) were measured for comparison with the eclipse plates.

17. The micrometer at the Royal Observatory is not suitable for the direct comparison of plates of this size. It was therefore decided to measure each plate by placing, film to film upon it, another photograph of the same region reversed by being taken through the glass. A photograph for this purpose was taken on July 18. This plate is regarded merely as an intermediary between the eclipse plates and comparison plates and is referred to as the scale plate, being used simply as a scale providing points of reference. In all cases measurement was made through the glass of the scale plate, adjusted on the eclipse or comparison plate which was being measured, so that the separation of the images on the two plates did not exceed one-third of a millimeter. The plates were held together by clips which insured contact over the whole surface. This method of measurement was found to be very convenient. Each plate was measured in two positions, being reversed through 180° , and the accordance of the result showed that the method of measurement was entirely satisfactory.

The measures, both direct and reversed, were made by two measurers (Mr. Davidson and Mr. Furner), and the means taken. There was no sensible difference between the measurers, which is satisfactory, as it affords evidence of the similarity of the images on the eclipse and comparison and scale plates.

The value of the micrometer screws (both in right ascension and declination) is $6.25''$.

18. The results of the measures are as follows:

TABLE II.—*Eclipse plates—scale.*

No. of star.	I.		II.		III.		IV.		V.		VII.		VIII.	
	Dz.	Dy.	Dz.	Dy.	Dz.	Dy.	Dz.	Dy.	Dz.	Dy.	Dz.	Dy.	Dz.	Dy.
11.....	r	r	r	r	r	r	r	r	r	r	r	r	r	r
5.....	-1.411	-0.554	-1.416	-1.324	+0.592	+0.955	+0.563	+1.238	+0.405	+0.970	-1.456	+0.964	r	r
.....	-1.048	- .338	-1.221	-1.312	+ .756	+ .843	+ .683	+1.225	+ .468	+ .881	-1.267	- .777	-1.285	-1.195
4.....	-1.216	+ .114	-1.054	- .944	+ .979	+1.172	+ .849	+1.524	+ .721	+1.167	-1.028	+1.142	- .927	-1.332
3.....	-1.237	+ .150	-1.079	- .862	+ .958	+1.244	+ .861	+1.587	+ .733	+1.130	-1.010	+1.185	- .897	- .894
6.....	-1.342	+ .124	-1.012	- .932	+1.052	+1.197	+ .894	+1.564	+ .798	+1.130	- .888	+1.125	- .838	- .937
10.....	-1.289	+ .205	- .909	- .948	+1.157	+1.211	+ .934	+1.522	+ .864	+1.119	- .920	+1.072	- .768	- .964
2.....	- .798	+ .109	- .733	-1.019	+1.256	+ .924	+1.177	+1.373	+ .985	+ .935	- .768	+ .892	- .585	-1.166
1 -1.500	- .584		-1.500	-1.324	+ .500	+ .843	+ .500	+1.226	+ .400	+ .861	-1.500	+ .777	-1.300	-1.332

Comparison plates—scale.

No. of star.	14 _{2a} .		14 _{3b} .		15 ₁ .		15 ₂ .		17 ₁ .		17 ₂ .		18 ₁ .	
	Dz.	Dy.	Dz.	Dy.	Dz.	Dy.	Dz.	Dy.	Dz.	Dy.	Dz.	Dy.	Dz.	Dy.
11.....	r	r	r	r	r	r	r	r	r	r	r	r	r	r
5.....	-0.478	-0.109	+0.967	+1.170	+1.098	+1.228	+0.725	+0.830	-1.073	-1.330	+1.242	-0.302	-1.188	-1.572
.....	- .544	- .204	+1.013	+1.192	+ .899	+1.232	+ .692	+ .938	-1.072	-1.075	+1.161	- .224	-1.195	-1.432
4.....	- .368	- .136	+1.030	+1.249	+1.133	+1.086	+ .725	+ .854	-1.296	-1.031	+1.354	- .281	-1.105	-1.454
3.....	- .350	- .073	+1.044	+1.305	+1.104	+1.114	+ .732	+ .883	-1.278	-1.014	+1.342	- .261	-1.178	-1.394
6.....	- .317	- .144	+ .980	+1.319	+1.214	+1.012	+ .714	+ .824	-1.052	-1.052	+1.363	- .390	-1.165	-1.473
10.....	- .272	- .146	+ .997	+1.327	+1.249	+ .960	+ .722	+ .831	-1.424	-1.038	+1.370	- .423	-1.104	-1.476
2.....	- .346	- .182	+1.102	+1.289	+ .969	+1.052	+ .734	+ .941	-1.236	- .909	+1.278	- .328	-1.164	-1.335
1 - .552	- .206		+ .967	+1.170	+ .899	+ .960	+ .690	+ .834	-1.424	-1.330	+1.161	- .423	-1.135	-1.572

¹ The numbers -1.500, -0.554, etc., given below the line, were taken out to make the values of Dz, Dy small and positive for arithmetical convenience.

19. The values of Dx and Dy were equated to expressions of the form

$$ax + by + c + \alpha E_x (= Dx)$$

and

$$dx + ey + f + \alpha E_y (= Dy),$$

where x, y are the coordinates of the stars given in Table I, and E_x, E_y are coefficients of the gravitational displacement.

The quantities c and f are corrections to zero, depending on the setting of the scale plate on the plate measured, a and e are differences of scale value, while b and d depend mainly on the orientation of the two plates. The quantity α denotes the deflection at unit distance (*i. e.*, 50' from the sun's center), so that αE_x and αE_y are the deflection in right ascension and declination, respectively, of a star whose coordinates are x and y .

The left-hand sides of the equation for the seven stars shown are:—

No.	Right ascension.	Declination.
11..	$c - 0.160b - 1.261a - 0.587\alpha...$	$f - 1.261d - 0.160e + 0.036\alpha...$
5...	$c - 1.107b - .160a - .557\alpha...$	$f - .160d - 1.107e - .789\alpha...$
4...	$c + .472b + .334a - .186\alpha...$	$f + .334d + .472e + 1.336\alpha...$
3...	$c + .360b + .348a - .222\alpha...$	$f + .348d + .360e + 1.574\alpha...$
6...	$c + 1.099b + .587a + .080\alpha...$	$f + .587d + 1.099e + .726\alpha...$
10..	$c + 1.321b + .860a + .158\alpha...$	$f + .860d + 1.321e + .589\alpha...$
2...	$c - .328b + 1.079a + 1.540\alpha...$	$f + 1.079d - .328e - .156\alpha...$

20. Normal equations formed from these equations of condition are as follows:

TABLE III.—*Eclipse plates, right ascension.*

	I.	II.	III.	IV.	V.	VII.	VIII.
$+7.000c + 1.657b + 1.787a + 0.226\alpha =$	$+2.159$	$+2.986$	$+3.250$	$+2.461$	$+2.185$	$+3.263$	$+2.648$
$+4.664 + 2.089 + 0.335 =$	-0.063	$+0.986$	$+1.320$	$+0.866$	$+1.051$	$+1.464$	$+1.130$
$+4.094 + 2.534 =$	$+1.034$	$+1.689$	$+1.866$	$+1.469$	$+1.480$	$+1.972$	$+1.723$
$+3.142 =$	$+0.712$	$+0.919$	$+0.924$	$+0.860$	$+0.844$	$+0.930$	$+0.973$
$+4.271b + 1.666a + 0.281\alpha =$	-0.575	$+0.278$	$+0.550$	$+0.283$	$+0.533$	$+0.691$	$+0.502$
$+3.683 + 2.476 =$	$+0.483$	$+0.928$	$+1.037$	$+0.841$	$+0.923$	$+1.140$	$+1.048$
$+3.135 =$	$+0.643$	$+0.823$	$+0.820$	$+0.781$	$+0.774$	$+0.826$	$+0.888$
$+2.988a + 2.366\alpha =$	$+0.707$	$+0.820$	$+0.822$	$+0.731$	$+0.715$	$+0.871$	$+0.852$
$+3.116 =$	$+0.681$	$+0.805$	$+0.784$	$+0.762$	$+0.739$	$+0.780$	$+0.855$
$+1.242\alpha =$	$+0.121$	$+0.156$	$+0.133$	$+0.183$	$+0.173$	$+0.090$	$+0.180$
$\alpha =$	$+0.098$	$+0.126$	$+0.107$	$+0.148$	$+0.140$	$+0.073$	$+0.145$
$a =$	$+0.158$	$+0.174$	$+0.189$	$+0.127$	$+0.128$	$+0.233$	$+0.169$
$b =$	-0.203	-0.011	$+0.048$	$+0.007$	$+0.042$	$+0.066$	$+0.042$

TABLE IV.—Comparison plates, right ascension.

	14 ₂₁ .	14 ₂₂ .	15 ₁ .	15 ₂ .	17 ₁ .	17 ₂ .	18 ₂ .
+7.000c +1.657b +1.787a +0.226α =	+1.190	+0.364	+1.463	+0.214	+1.214	+0.983	+0.146
+4.664 +2.089 +0.335 =	+0.700	+0.017	+0.992	+0.078	-0.340	+0.603	+0.083
+4.094 +2.535 =	+0.633	+0.220	+0.499	+0.073	-0.172	+0.450	+0.085
+3.142 =	+0.253	+0.159	-0.029	+0.037	-0.164	+0.105	+0.041
+4.271b +1.666a +0.281α =	+0.418	-0.069	+0.645	+0.027	-0.627	+0.370	+0.048
+3.683 +2.476 =	+0.334	+0.127	+0.126	+0.018	-0.451	+0.199	+0.048
+3.135 =	+0.215	+0.147	-0.076	+0.030	-0.203	+0.074	+0.036
+2.988a +2.366α =	+0.172	+0.154	-0.126	+0.007	-0.236	+0.055	+0.029
+3.116 =	+0.188	+0.152	-0.119	+0.028	-0.162	+0.050	+0.033
+1.242α =	+0.052	+0.030	-0.019	+0.022	+0.025	+0.006	+0.010
α =	+0.042	+0.024	-0.015	+0.018	+0.020	+0.005	+0.008
a =	+0.024	+0.032	-0.030	-0.012	-0.094	+0.014	+0.003
b =	+0.086	-0.030	+0.164	+0.012	-0.111	+0.081	+0.010

TABLE V.—Eclipse plates, declination.

	I.	II.	III.	IV.	V.	VII.	VIII.
+7.000f +1.787d +1.657e +3.316α =	+3.688	+1.927	+1.646	+1.452	+1.389	+1.718	+1.906
+4.094 +2.089 +1.840 =	+2.200	+1.168	+0.719	+0.823	+0.555	+0.610	+0.840
+4.664 +3.694 =	+1.860	+1.159	+1.129	+0.984	+0.874	+1.023	+1.103
+5.784 =	+2.657	+1.681	+1.535	+1.361	+1.335	+1.545	+1.707
+3.638d +1.666e +0.994α =	+1.260	+0.677	+0.299	+0.453	+0.201	+0.172	+0.354
+4.271 +2.908 =	+0.986	+0.702	+0.739	+0.640	+0.545	+0.616	+0.741
+4.212 =	+0.909	+0.768	+0.755	+0.673	+0.677	+0.731	+0.804
+3.508e +2.453α =	+0.409	+0.392	+0.602	+0.431	+0.453	+0.537	+0.579
+3.941 =	+0.565	+0.523	+0.673	+0.549	+0.622	+0.684	+0.707
+2.224α =	+0.279	+0.309	+0.252	+0.247	+0.305	+0.308	+0.302
α =	+0.126	+0.139	+0.114	+0.111	+0.137	+0.139	+0.136
e =	+0.029	+0.015	+0.092	+0.045	+0.033	+0.056	+0.070
d =	+0.299	+0.141	+0.009	+0.074	+0.003	-0.016	+0.028

TABLE VI.—Comparison plates, declination.

	14 ₂₅ .	14 ₂₆ .	15 ₁ .	15 ₂ .	17 ₁ .	17 ₂ .	18 ₂ .
+7.000 <i>f</i> +1.787 <i>d</i> +1.657 <i>e</i> +3.316 α =	+0.446	+0.661	+0.964	+0.343	+1.861	+0.752	+0.868
+4.094 +2.089 +1.840 =	+0.060	+0.420	-0.156	+0.140	+1.038	+0.041	+0.476
+4.664 +3.694 =	+0.202	+0.394	-0.203	-0.117	+0.526	-0.110	+0.122
+5.784 =	+0.380	+0.482	+0.220	+0.044	+1.004	+0.296	+0.419
+3.638 <i>d</i> +1.666 <i>e</i> +0.994 α =	-0.054	+0.251	-0.402	+0.053	+0.563	+0.151	+0.255
+4.271 +2.908 =	+0.096	+0.237	-0.431	-0.198	+0.085	-0.288	-0.084
+4.212 =	+0.168	+0.169	-0.237	-0.119	+0.122	-0.060	+0.008
+3.508 <i>e</i> +2.453 α =	+0.121	+0.122	-0.247	-0.222	-0.173	-0.219	-0.201
+3.941 =	+0.183	+0.100	-0.127	-0.133	-0.032	-0.019	-0.062
+2.224 α =	+0.098	+0.015	+0.046	+0.022	+0.089	+0.134	+0.079
α =	+0.044	+0.007	+0.021	+0.010	+0.040	+0.060	+0.036
e =	+0.004	+0.030	-0.085	-0.070	-0.077	-0.104	-0.082
d =	-0.028	+0.054	-0.077	+0.044	+0.179	-0.010	+0.098

21. The values of α are collected in Table VII:

TABLE VII.

Right ascension.		Declination.	
Eclipse—scale.	Comparison—scale.	Eclipse—scale.	Comparison—scale.
r	r	r	r
+0.098	+0.042	+0.126	+0.044
+0.126	+0.024	+0.139	+0.007
+0.107	-0.015	+0.114	+0.021
+0.148	+0.018	+0.111	+0.010
+0.140	+0.020	+0.137	+0.040
+0.073	+0.005	+0.139	+0.060
+0.145	+0.008	+0.136	+0.036
Mean +0.120	+0.015	+0.129	+0.031

By subtraction the α of the comparison plates the scale plate is eliminated, and we derive from right ascensions $\alpha = +0.105r$ and from declinations $\alpha = +0.098r$.

Reference to the normal equations shows that the declination result is of double the weight of that from the right ascensions.

Thus

$$\alpha = +0.100r = +0.625''.$$

This is at a distance 50' from the sun's center. At the time of the eclipse the sun's radius was 15.8'; thus the deflection at the limb is 1.98''.

The range in the values of α is attributable to the errors inherent to the star images of the different plates, and can not be reduced by

further measurement. The mean values $+0.015''$ and $0.031''$ arise from the errors in the intermediary scale plate.

22. The probable error of the result judging from the accordance of the separate determinations is about 6 per cent. It is desirable to consider carefully the possibility of systematic error. The eclipse and comparison photographs were taken under precisely similar instrumental conditions, but there is the difference that the eclipse photographs were taken on the day of May 29, and the comparison photographs on nights between July 14 and July 18. A very satisfactory feature of the photographs is the essential similarity of the star images on the two sets of photographs.

The satisfactory accordance of the eclipse and comparison plates is shown by a study of the plate constants. The following corrections for differential refraction and aberration are calculated from the times and dates of exposure.

	a.	e.	b.	d.
	<i>r</i>	<i>r</i>	<i>r</i>	<i>r</i>
Eclipse plates.....	+0.240	+0.168	+0.062	+0.062
Scale plate.....	+ .423	+ .207	+ .096	+ .096
Comparison 14 _a	+ .409	+ .207	+ .091	+ .091
14 _b	+ .409	+ .207	+ .091	+ .091
15 _a	+ .390	+ .207	+ .087	+ .087
15 _b	+ .370	+ .202	+ .087	+ .087
17 _a	+ .399	+ .207	+ .091	+ .091
17 _b	+ .337	+ .202	+ .077	+ .077
18 _a	+ .327	+ .202	+ .072	+ .072

When these are applied to the values of the constants found from the normal equations we find the following values of the scale of the several photographs and their orientation relative to the scale plate:

	Scale value.		Orientation.		Adopted scale and orientation. S Ω	
	From z.	From y.	From z.	From y.		
	<i>r</i>	<i>r</i>	<i>r</i>	<i>r</i>	<i>r</i>	<i>r</i>
Eclipse I.....	-0.025	-0.010	-0.237	-0.265	0.000	-0.251
II.....	- .009	- .024	- .045	- .107	0.000	- .076
III.....	+ .006	+ .053	+ .014	+ .025	0.000	+ .020
IV.....	- .056	+ .006	- .027	- .040	0.000	- .034
V.....	- .055	- .006	+ .008	+ .031	0.000	+ .020
VII.....	+ .050	+ .017	+ .032	+ .050	0.000	+ .041
VIII.....	- .014	+ .031	+ .008	+ .006	0.000	+ .007
Comparison 14 _a	+ .010	+ .004	+ .081	+ .033	+0.013	+ .057
14 _b	+ .018	+ .030	- .035	- .049	+ .013	- .042
15 _a	- .063	- .085	+ .155	+ .086	- .084	+ .120
15 _b	- .065	- .075	+ .003	- .035	- .084	- .016
17 _a	- .118	- .077	- .116	- .174	- .084	- .145
17 _b	- .072	- .109	+ .062	+ .029	- .084	+ .046
18 _a	- .093	- .087	- .014	- .074	- .084	- .044

The agreement in the scale values obtained from α and γ is satisfactory. There appears to be a small difference in the orientations as derived from the two directions in the comparison plates. This is, however, of small importance in the determination of α . There is a difference of scale value from July 15-18 shown in both coordinates. For the purpose of exhibiting the gravitational displacements residuals have been computed using adopted values for the scale and orientation given above along with the calculated corrections for differential refraction and aberration. This has the advantage of reducing the number of constants employed in the reduction of the plates and lessens the possibility of masking any discordances, though greater irregularities necessarily appear when four arbitrary constants instead of six are used in the reduction of each plate. The quantities are converted from revolutions to seconds of arc, as the more familiar unit facilitates judgment of the results.

TABLE VIII.—Comparison of the Eclipse and comparison photographs with the scale plate after correction for differential refraction and aberration, orientation, and change of scale.

ECLIPSE PLATES, RIGHT ASCENSION.

No. of star.	I.	II.	III.	IV.	V.	VII.	VIII.	Mean.
"	"	"	"	"	"	"	"	"
11.....	-0.18	-0.51	-0.46	-0.07	-0.04	-0.72	-0.43	-0.34
5.....	-.45	-.81	-.38	-.58	-.60	-.36	-.62	-.54
4.....	+.08	+.11	-.08	-.11	-.11	-.16	-.18	-.06
3.....	-.23	-.11	-.19	-.05	-.02	-.02	-.01	-.09
6.....	-.14	+.23	-.09	-.11	-.13	+.13	-.08	-.03
10.....	+.17	+.06	+.14	-.18	-.11	+.14	-.01	+.03
2.....	+.75	+1.03	+1.06	+1.09	+1.01	+.98	+1.30	+1.03

ECLIPSE PLATES, DECLINATION.

11.....	0.00	-.00	-0.03	+0.02	+0.17	+0.16	+0.01	+0.03
5.....	-.38	-.54	-.61	-.30	-.39	-.73	-.81	-.54
4.....	+1.19	+1.04	+1.03	+.98	+1.11	+1.19	+1.24	+1.11
3.....	+1.42	+1.58	+1.50	+1.39	+1.55	+1.49	+1.49	+1.49
6.....	+.65	+.79	+1.01	+.97	+.71	+.95	+1.01	+.87
10.....	+.62	+.46	+1.03	+.54	+.56	+.58	+.74	+.65
2.....	+.01	+.25	-.40	-.09	-.22	-.14	-.17	-.11

COMPARISON PLATES, RIGHT ASCENSION.

	14 _{2a} .	14 _{2b} .	15 ₁ .	15 ₂ .	17 ₁ .	17 ₂ .	18 ₂ .	Mean.
"	"	"	"	"	"	"	"	"
11.....	-0.19	-0.24	-0.23	-0.23	+0.11	-0.19	-0.02	-0.15
5.....	-.42	+.16	-.36	-.32	-.24	-.33	-.26	-.25
4.....	-.01	+.03	-.01	+.05	-.04	+.23	+.08	+.05
3.....	+.14	+.09	+.28	+.10	-.03	+.21	-.01	+.11
6.....	+.02	-.18	+.26	+.06	+.13	+.03	+.14	+.07
10.....	+.17	-.06	+.20	+.18	+.13	-.02	+.15	+.11
2.....	+.31	+.18	-.16	+.22	-.04	+.08	-.06	+.08

TABLE VIII.—*Comparison of the Eclipse and comparison photographs, etc.—Con.*
COMPARISON PLATES, DECLINATION.

11.....	-0.07	+0.08	-0.26	-0.04	-0.26	-0.18	-0.16	-0.13
5.....	-.23	-.03	+.03	.00	-.19	+.03	-.20	-.08
4.....	+.23	+.05	+.29	+.18	+.45	+.53	+.23	+.28
3.....	+.64	+.41	+.42	+.36	+.48	+.60	+.54	+.49
6.....	+.22	+.36	+.33	+.26	+.41	+.21	+.32	+.30
10.....	+.28	+.32	+.31	+.36	+.36	+.15	+.29	+.30
2.....	+.25	+.14	+.18	+.21	+.09	-.03	+.27	+.16

Subtracting the results of the comparison plates so as to eliminate the errors arising from the intermediary scale plate we find for the displacements of the different stars, as compared with those as given by Einstein's theory, with value $1.75''$ at the sun's limb:

No. of star.	Displacement in right ascension.		Displacement in declination.	
	Observed.	Calculated.	Observed.	Calculated.
	"	"	"	"
11.....	-0.19	-0.32	+0.16	+0.02
5.....	-.29	-.31	-.46	-.43
4.....	-.11	-.10	+.83	+.74
3.....	-.20	-.12	+1.00	+.87
6.....	-.10	+.04	+.57	+.40
10.....	-.08	+.09	+.35	+.32
2.....	+.95	+.85	-.27	-.09

[The sign of the displacement in right ascension of No. 6 was printed in Philosophical Transactions of the Royal Society of London as +. This and several other typographical errors, kindly pointed out by Prof. Bauer, have been corrected.]

PHOTOGRAPHS TAKEN WITH THE ASTROGRAPHIC OBJECT GLASS.

23. As stated above, these photographs were taken with the astrographic object glass stopped down to 8 inches, mounted in a steel tube and fed by a 16-inch cœlost. From many years' experience with the object glass at Greenwich it is certain that when the object glass is mounted in a steel tube the change of scale over a range of temperature of 10° F. should be insignificant, and the definition should be very good. It was realized that this high standard would not be obtained with the glass used in conjunction with the cœlost taken to Brazil, but nevertheless the results shown when the plates were developed were very disappointing. The images were diffused and apparently out of focus, although on the night of May 27 the focus was good.⁶ Worse still, this change was temporary, for with-

⁶ The following note made at the time is quoted in full: "May 30, 3 a. m., four of the astrographic plates were developed, and when dry examined. It was found that there had been a serious change of focus, so that, while the stars were shown, the definition was spoiled. This change of focus can only be attributed to the unequal expansion of the mirror through the sun's heat. The readings of the focussing scale were checked next day, but were found unaltered at 11.0 millimeters. It seems doubtful whether much can be got from these plates."

out any change in the adjustments, the instrument had returned to focus when the comparison plates were taken in July.

These changes must be attributed to the effect of the sun's heat on the mirror, but it is difficult to say whether this caused a real change of scale in the resulting photographs or merely blurred the images.

The photographs were measured in the astrographic duplex micrometer, the eclipse photographs being directly compared with the comparison plates taken in July. All the stars shown were measured. They were reduced by the same method as that employed for the "4-inch" photographs. With the exception of plates Nos. 15 and 16, taken through clouds, the stars numbered 3, 4, 5, 6, 10, 11, and 12 are shown on all the plates; the fainter stars 2, 7, 8, and 9 are sometimes shown, but No. 1, which is very near the sun, is always drowned in the corona. These plates were only measured in declination, as the right ascensions without No. 1 are of little weight.

24. In the following table is given the value of α , the constant of the gravitational displacement, as calculated from the measures; the apparent difference of scale e between the eclipse and comparison plates; d , the difference of orientation of the plates given by the measures of γ and depending on the adjustment of the plates in the measuring machine.

TABLE IX.

(1"=12.3".)

No. of eclipse plate.	Reference No. of comparison plate.	Number of stars.	Values of d , e , α in revolutions at 50" distance.			α at sun's limb in arc.
			d .	e .	α .	
			r	r	r	"
1.....	18 ₄	7	+0.051	+0.069	+0.033	+1.28
2.....	18 ₄	11	-.009	+.059	+.025	+.97
3.....	18 ₄	8	-.074	+.101	+.028	+1.09
4.....	18 ₄	11	-.168	+.091	+.033	+1.28
5.....	11 ₅	10	+.094	+.076	+.025	+.97
6.....	11 ₅	11	+.186	+.082	+.021	+.82
7.....	14 ₃	12	+.006	+.119	.000	.00
7.....	18 ₅	7	-.054	+.166	.000	.00
8.....	14 ₃	10	+.093	+.064	+.021	+.82
9.....	17 ₄	7	-.096	+.129	+.008	+.31
10.....	17 ₄	10	+.090	+.045	+.026	+1.01
11.....	11 ₁	10	+.073	+.061	+.032	+1.24
12.....	11 ₁	11	-.009	+.102	+.049	+1.91
12.....	17 ₅	7	-.102	+.114	+.019	+.74
15.....	15 ₅	6	+.111	+.036	+.018	+.70
16.....	15 ₅	7	-.002	+.037	+.018	+.70
17.....	17 ₅	8	-.022	+.109	+.012	+.47
18.....	17 ₅	7	+.045	.000	+.030	+1.17
Mean.....				+.082	+.022	+0.86

Thus the mean value of α obtained from all the astrographic plates is $0.86''$, a figure considerably less than that obtained from the 4-inch photographs.

25. Reference to the diagram shows that the measurement of displacement depends essentially on the position of the stars Nos. 3 and 4 relative to 5 on one side and 6 and 10 on the other. These are all bright stars, and in this respect their images are more comparable than are the images of the fainter stars. The measures of these stars are given in the following table:

No. of eclipse plate.	Measured values of Dy for stars Nos.—					No. of eclipse plate.	Measured values of Dy for stars Nos.—				
	5	4	3	6	10		5	4	3	6	10
	r	r	r	r	r		r	r	r	r	r
1.....	-0.051	+0.175	+0.169	+0.201	+0.235	9.....	-0.059	+0.121	+0.109	+0.205	+0.180
2.....	+0.558	+0.656	+0.724	+0.663	+0.702	10.....	+0.033	+0.270	+0.188	+0.253	+0.230
3.....	+0.124	+0.285	+0.286	+0.274	+0.355	11.....	+0.025	+0.215	+0.210	+0.233	+0.274
4.....	+0.111	+0.222	+0.247	+0.231	+0.167	12.....	-0.068	+0.144	+0.124	+0.160	+0.167
5.....	+0.034	+0.228	+0.232	+0.213	+0.308	15.....	-0.038	+0.138	+0.107	+0.172	.....
6.....	+0.164	+0.488	+0.478	+0.557	+0.637	16.....	-0.050	+0.076	+0.046	+0.127	+0.073
7.....	-0.051	+0.156	+0.162	+0.250	+0.279	17.....	-0.071	+0.104	+0.081	+0.186	+0.164
8.....	+0.108	+0.330	+0.314	+0.376	+0.397	13.....	+0.016	+0.092	+0.109	+0.099	+0.034

The equations given by these stars are:

$$-0.160d - 1.107e - 0.789\alpha + f = Dy_5 \quad (1)$$

$$+0.334d + 0.472e + 1.336\alpha + f = Dy_4 \quad (2)$$

$$+0.348d + 0.360e + 1.574\alpha + f = Dy_3 \quad (3)$$

$$+0.587d + 1.099e + 0.726\alpha + f = Dy_6 \quad (4)$$

$$+0.860d + 1.321e + 0.589\alpha + f = Dy_{10} \quad (5)$$

The mean of (4) and (5) added to (1) gives

$$+0.564d + 0.103e - 0.131\alpha + 2f = Dy_5 + \frac{1}{2}(Dy_6 + Dy_{10}).$$

While the sum of (2) and (3) gives

$$+0.682d + 0.832e + 2.910\alpha + 2f = Dy_3 + Dy_4.$$

Subtracting these we get

$$3.041\alpha + 0.729e + 0.118d = Dy_3 + Dy_4 - Dy_5 - \frac{1}{2}(Dy_6 + Dy_{10}).$$

This equation has a small coefficient for e and a very small one for d .

Calculating the quantities on the right-hand side, assuming e to be the same for all the plates, and substituting the values of d from the previous table, we find:

r		r	
$\alpha + 0.240e = +0.056$	1	$\alpha + 0.240e = +0.035$	9
$\alpha + 0.240e = +0.049$	2	$\alpha + 0.240e = +0.048$	10
$\alpha + 0.240e = +0.047$	3	$\alpha + 0.240e = +0.045$	11
$\alpha + 0.240e = +0.059$	4	$\alpha + 0.240e = +0.059$	12
$\alpha + 0.240e = +0.050$	5	$\alpha + 0.283e = +0.026$	15
$\alpha + 0.240e = +0.059$	6	$\alpha + 0.240e = +0.024$	16
$\alpha + 0.240e = +0.036$	7	$\alpha + 0.240e = +0.028$	17
$\alpha + 0.240e = +0.046$	8	$\alpha + 0.240e = +0.029$	18

In photograph No. 15, star 10 is not shown, and the equation is slightly modified. It may also be noticed that the values are somewhat smaller for Nos. 15 to 18.

The means of the 16 photographs treated in this manner give

$$\alpha + 243e = +0.0435'',$$

or with the value of the scale $0.082''$ from the previous table

$$\alpha = +0.024'' = 0.93'' \text{ at the limb.}$$

It may be noticed that the change of scale arising from differences of refraction and aberration is $0.020''$. If this value of e be taken instead of $0.082''$ we obtain

$$\alpha = +0.039'' = +1.52'' \text{ at the sun's limb.}$$

The equations on page 155 were also solved by least squares for each plate. There is a considerable range in the deduced values of α , as is to be expected when α and e are determined independently for each plate. The mean result for α is $0.99''$, or very nearly the same as that already found.

The photographs taken with the astrographic telescope support those obtained by the "4-inch" to the extent that they show considerable outward deflection, but for the reasons already given are of much less weight.

IV. THE EXPEDITION TO PRINCIPE.

[Observers, Prof. A. S. Eddington and Mr. E. T. Cottingham.]

26. The expedition left Liverpool on the *Anselm* on March 8, and traveled in company with the Sobral expedition as far as Madeira. It was necessary to wait there until April 9, when the journey was continued on the *Portugal*, belonging to the Companhia Nacional de Navegação. The expedition landed at the small port of San Antonio in the Isle of Principe on April 23.

Vice Admiral Campos Rodrigues and Dr. F. Oom of the National Observatory, Lisbon, had kindly given us introductions, and everything possible was done by those on the island for the success of the work and the comfort of the observers. We were met on board by the acting administrator Sr. Vasconcelos, Sr. Carneiro, president of the Association of Planters, and Sr. Grageira, representing the Sociedade d'Agricultura Colonial, who made all necessary arrangements. The Portuguese Government dispensed with any customs examination of the baggage.

27. Principe is a small island belonging to Portugal, situated just north of the equator in the Gulf of Guinea, about 120 miles from the African coast. The extreme length and breadth are about 10 miles and 6 miles. Near the center mountains rise to a height of 2,500 feet, which generally attract heavy masses of cloud. Except

for a certain amount of virgin forest, the island is covered with coco plantations. The climate is very moist, but not unhealthy. The vegetation is luxuriant, and the scenery is extremely beautiful. We arrived near the end of the rainy season, but the gravana, a dry wind, set in about May 10, and from then onwards no rain fell except on the morning of the eclipse.

We were advised that the prospects of clear sky at the end of May were not very good, but that the best chance was on the north and west of the island. After inspecting two other sites on the property of the Sociedade d'Agricultura Colonial, we fixed on Roça Sundy, the headquarters of Sr. Carneiro's chief plantation. We were Sr. Carneiro's guests during our whole visit, and used freely his ample resources of labor and material at Sundy. We learned later that he had postponed a visit to Europe in order to entertain us. We were also greatly indebted to his manager at Sundy, Sr. Atalaya, with whom we lived for five weeks; his help and attention were invaluable. Mr. Wright and Mr. Lewis of the cable station kindly assisted us as interpreters when necessary.

Sundy is situated in the northwest of the island overlooking the sea at a height of 500 feet, and as far as possible from the cloud-gathering peaks. Our telescope was erected in a small walled inclosure adjoining the house, from which the ground sloped steeply down to the sea in the direction of the sun at eclipse. On the other side it was sheltered by a building. The approximate position was latitude $1^{\circ} 40' N.$, longitude $29m. 32s. E.$

28. The baggage was brought to Sundy on April 28 mainly by tram, but with a break of about a kilometer, where it had to be transported through the woods by native carriers. After a week spent on the preparations, we returned to San Antonio for the week May 6-13, as it was undesirable to unpack the mirror so early in the damp climate. On our return to Sundy the installation and adjustments were soon completed, and the first check plates were taken on May 16. Meanwhile the gravana had begun, which, although there is no rain, is generally accompanied by increased clouds. There were, however, some days of clear sky, and the nights were usually clear.

The cœlostat was mounted on a stone pier built for the purpose. The clock weight fell into a pit below the clock deep enough to allow a run of 36 minutes without rewinding. Care was taken to use a particular part of the cœlostat sector, considered to be the most perfect, in photographing the eclipse and the check field. The telescope (Oxford astrographic object glass, see p. 137) rested on wooden Vs near the two ends, the Vs being supported on packing cases; the one at the breech end could be moved laterally to allow

of different declination settings, and was marked with an approximate declination scale. A series of exposures of one second was made on a bright star to test whether there was any shake of the telescope after inserting the plate; no shake was detected even when the exposure was made immediately; but as a safeguard for the eclipse photographs a full second was allowed to elapse before beginning the exposure. The exposure was made by moving a cardboard screen unconnected with the instrument. The telescope pointed slightly downward, and the tube was turned so as to give the right orientation to the plate, the lines of declination being 2° or 3° inclined to the horizontal. A canvas screen was arranged to protect the tube and object glass from the direct radiation of the sun.

The adjustments call for little comment. In view of the purpose of the observations it was desirable to adjust the tilt of the object glass and plate with special care. It was also important that the setting on the field should be nearly exact. The sun appeared on the eclipse day in sufficient time to allow of the setting being made by means of the solar image; but arrangements had been tested by which the correct field would have been obtained if it had been cloudy up to totality.* The telescope was focused by trial photographs of stars, and owing to the uniform temperature of the island the focus was unchanged for day observations.

The object glass was stopped down to 8 inches for the eclipse photographs and for all check and comparison photographs used in the reductions.

29. The days preceding the eclipse were very cloudy. On the morning of May 29 there was a very heavy thunderstorm from about 10 a. m. to 11.30 a. m.—a remarkable occurrence at that time of year. The sun then appeared for a few minutes, but the clouds gathered again. About half an hour before totality the crescent sun was glimpsed occasionally, and by 1.55 it could be seen continuously through drifting clouds. The calculated time of totality was from 2 hours 13 minutes 5 seconds, to 2 hours 18 minutes 7 seconds, Greenwich mean time. Exposures were made according to the prepared program, and 16 plates were obtained. Mr. Cottingham gave the exposures and attended to the driving mechanism, and Professor Eddington changed the dark slides. It appears from the results that the cloud must have thinned considerably during the last third of totality, and some star images were shown on the later plates. The cloudier plates give very fine photographs of a remarkable prominence, which was on the limb of the sun.

A few minutes after totality the sun was in a perfectly clear sky, but the clearance did not last long. It seems likely that the break-up

* The method depended on setting the cross wires of the theodolite (attached to the *cœlost*at) on a terrestrial mark, and then starting the clock at a particular instant.

of the clouds was due to the eclipse itself, as it was noticed that the sky usually cleared at sunset.

It had been intended to complete all the measurements of the photographs on the spot; but owing to a strike of the steamship company it was necessary to return by the first boat, if we were not to be marooned on the island for several months. By the intervention of the administrator, berths, commandeered by the Portuguese Government, were secured for us on the crowded steamer. We left Principe on June 12, and after transshipping at Lisbon reached Liverpool on July 14.

30. The following is a list of the photographs, including the comparison photographs kindly taken for us by Mr. F. A. Bellamy at Oxford, before the instrument was dismounted. All the eclipse photographs are given though only W and X furnished results. Of the other series only the exposures actually used in the reductions are given.

List of plates.

Check Field (R. A. 14h. 12m. 47s., declination $+20^{\circ} 30'$).

Reference.	Place.	Date.	Local sidereal time.	Exposure.	Approx. Z. D.	Barometer.	Thermometer.	Plate.
		1919.	<i>h. m. s.</i>	<i>s.</i>	<i>°</i>	<i>in.</i>	<i>°</i>	
<i>a</i> ₁	Oxford....	Jan. 16	12 55 10	60	35	29.64	37.0	S.
<i>b</i> ₁.....	...do.....	17	13 10 40	60	34	29.83	35.3	S.
<i>c</i> ₁.....	...do.....	17	13 54 55	60	31	29.83	35.3	S.
<i>d</i> ₁.....	...do.....	17	14 9 25	60	31	29.83	35.3	S.
<i>e</i> ₁.....	...do.....	23	13 13 30	60	33	30.45	29.0	S.

Reference.	Place.	Date.	Greenwich mean time.	Exposure.	Approx. Z. D.	Barometer.	Thermometer.	Plate.
		1919.	<i>h. m. s.</i>	<i>s.</i>	<i>°</i>	<i>in.</i>	<i>°</i>	
<i>q</i> ₁	Principe..	May 22	12 25 40	40	43	29.45	76.5	S.R.
<i>r</i> ₁.....	...do.....	22	12 31 20	40	45	29.45	76.5	S.R.
<i>s</i> ₁.....	...do.....	22	12 37 50	80	46	29.45	76.5	S.R.
<i>v</i> ₁.....	...do.....	25	12 22 20	40	45	29.45	76.5	S.S.
<i>w</i> ₁.....	...do.....	25	12 26 20	40	46	29.45	76.5	S.S.

Eclipse Field (R. A. 4h. 19m. 30s., declination $+21^{\circ} 43'$).

Reference.	Place.	Date.	Local sidereal time.	Exposure.	Approx. Z. D.	Barometer.	Thermometer.	Plate.
		1919.	<i>h. m. s.</i>	<i>s.</i>	<i>°</i>	<i>in.</i>	<i>°</i>	
<i>D</i> ₁	Oxford....	Jan. 16	3 58 1	5	30	29.65	39.0	S.
<i>G</i> ₁.....	...do.....	22	4 4 39	5	30	30.30	31.0	S.
<i>H</i> ₁.....	...do.....	22	4 34 28	5	30	30.30	31.0	S.
<i>I</i> ₁.....	...do.....	22	4 48 46	10	31	30.30	31.0	S.
<i>K</i> ₁.....	...do.....	Feb. 9	4 45 24	10	30	30.48	24.5	S.

List of plates—Continued.

Reference.	Place.	Date.	Greenwich mean time.	Expo- sure.	Approx. Z. D.	Barom- eter.	Ther- mometer.	Plate.
		1919.	<i>a. m. s.</i>	<i>s.</i>	<i>°</i>	<i>in.</i>	<i>°</i>	
K'.....	Principe.	May 29	2 13 9	5	46	29.45	77.0	S.R.
L.....	do.	29	2 13 28	10	46	29.45	77.0	S.R.
M.....	do.	29	2 13 46	3	46	29.45	77.0	S.R.
N.....	do.	29	2 14 1	5	46	29.45	77.0	E.
O.....	do.	29	2 14 20	10	46	29.45	77.0	S.S.
P.....	do.	29	2 14 44	15	46	29.45	77.0	S.S.
Q.....	do.	29	2 15 6	5	46	29.45	77.0	S.R.
R.....	do.	29	2 15 30	20	46	29.45	77.0	S.R.
S.....	do.	29	2 15 53	3	46	29.45	77.0	S.S.
T.....	do.	29	2 16 13	15	46	29.45	77.0	E.
U.....	do.	29	2 16 37	10	46	29.45	77.0	S.R.
V.....	do.	29	2 16 56	5	46	29.45	77.0	S.S.
W.....	do.	29	2 17 15	10	46	29.45	77.0	S.
X.....	do.	29	2 17 33	3	46	29.45	77.0	S.R.
Y.....	do.	29	2 17 47	2	46	29.45	77.0	S.R.
Z.....	do.	29	2 18 1	2	46	29.45	77.0	S.R.

NOTES.

Column 1. The letter is marked on the original plates (preserved at Cambridge Observatory). The number refers to the exposure, disregarding exposures taken without the 8-inch stop.

Column 2. The coordinates of Oxford Observatory are 5m. 3s. W., 51° 46' N., and of the site at Principe, 29m. 32s. E., 1° 40' N.

Column 4. The mid instant of the exposure is given. Times for check plates at Principe were only noted roughly. Times for the eclipse plates are deduced from the calculated time of totality, the interval from the end of one exposure to the beginning of the next being assumed uniform.

Column 7. Readings at Principe were taken with an aneroid recording instrument, and therefore automatically reduced to the latitude of England. The barometer during our visit was practically constant, except for a regular semidiurnal wave of amplitude about 0.05 inch.

Column 9. Brand of plate: S., Imperial Sovereign; S. S., Imperial Special Sensitive; S. R., Ilford Special Rapid; E., Ilford Empress. Backed plates were used at Principe.

The large proportion of Ilford Special Rapid plates used at the eclipse was due to the fact that experience in developing the check plates showed that these suffered less than the others from the high temperature of the water (78° F.). Ice was generally available for the check plates through the kindness of Sr. Grageira; but the supply failed after the eclipse, and formalin was used to harden the films. This was unsatisfactory except for the Ilford Special Rapid plates, and so plates P, S, T, W were brought home undeveloped. The developing at Principe was done at night, and the drying was accelerated by use of alcohol.

The use of an 8-inch stop in front of the object glass was suggested to us by Mr. Davidson, who showed that a great improvement of the images resulted; it was originally intended, however, to use the full aperture for part of totality. Early measures of check plates made at Principe soon convinced us that the results from the full aperture

were greatly inferior, and we decided to rely entirely on the 8-inch aperture.

THE CHECK PLATES.

31. In addition to the eclipse field, a check field was photographed both at Oxford and at Principe. The field chosen included Arcturus, so that it was easily found with the cœlostæt. Its declination was nearly the same as that of the eclipse field, and it was photographed at the same altitude at Principe in order that any systematic error, due to imperfections of the cœlostæt mirror or other causes, might affect both sets of plates equally. The primary purpose was thus to check the possibility of systematic error arising from the different conditions of observation at Oxford and Principe, and from possible changes in the object glass during transit. Unlike the Sobral expedition, we were not able to take comparison photographs of the eclipse field at Principe, because for us the eclipse occurred in the afternoon, and it would be many months before the field could be photographed in the same position in the sky before dawn. The check plates were therefore specially important for us.

As events turned out the check plates were important for another purpose, viz, to determine the difference of scale at Oxford and Principe. As shown in the report of the Sobral expedition, it is not necessary to know the scale of the eclipse photographs, since the reductions can be arranged so as to eliminate the unknown scale. If, however, a trustworthy scale is known and used in the reductions, the equations for the deflection have considerably greater weight, and the result depends on the measurement of a larger displacement. On surveying the meager material which the clouds permitted us to obtain, it was evident that we must adopt the latter course; and accordingly the first step was to obtain from the check plates a determination of the scale of the Principe photographs.

32. All the measures were made by Professor Eddington with the Cambridge measuring machine.* An Oxford and a Principe plate were placed film to film so that the images of corresponding stars nearly coincided—this was possible because the Oxford plates were taken direct, and the Principe plates by reflection in the cœlostæt mirror.

The small differences Δx and Δy , in the sense Principe-Oxford, were then measured for each star. Eight settings were made on each image; for half of them the field was rotated through 180° by the reversion prism. Five pairs of plates were measured, and the measures are given in Table XI.

* Monthly Notices, R. A. S., Vol. LXI, p. 444.

TABLE XI.—*Check plates, measures.*

Star.	Approximate coordinates.		q_1-a_1 .		w_1-b_1 .		s_1-c_1 .		r_1-d_1 .		v_1-e_1 .	
	x .	y .	Δx .	Δy .	Δx .	Δy .	Δx .	Δy .	Δx .	Δy .	Δx .	Δy .
1.....	1.41	20.31	4,346	7,180	3,199	4,259	6,012	7,375	3,921	8,796	5,435	4,399
2.....	5.89	12.74	3,865	6,405	3,394	4,129	4,922	6,132	3,039	7,440	5,978	4,170
4.....	9.46	11.13	3,640	5,932	3,408	4,118	4,369	5,366	2,638	6,776	5,966	4,441
5.....	12.00	6.84	3,311	5,590	.....	.....	3,831	4,752	1,938	6,156	.....	4,314
6.....	12.80	27.33	5,415	6,561	3,192	5,140	7,689	5,925	5,379	7,580	5,032	5,794
7.....	13.75	13.78	4,076	5,630	3,496	4,290	4,891	4,805	3,101	6,461	5,906	4,826
8.....	15.50	24.38	5,125	6,300	.....	.....	.....	.....	.....	.....	5,139	5,412
10.....	20.13	10.49	3,965	4,940	3,679	4,505	4,656	3,568	2,866	5,370	6,398	5,229
11.....	20.81	0.93	2,874	4,352	3,876	3,759	2,845	2,815	1,238	4,758	7,268	4,482
12.....	22.91	6.23	3,685	4,436	3,931	4,158	4,039	2,738	2,270	4,551	6,765	5,076
13.....	26.46	8.96	4,222	4,238	4,045	4,326	4,724	2,232	2,720	4,120	6,836	5,561

The unit for x and y is 5 millimeters, which is approximately equal to 5'. The differences Δx , Δy are given in units of the fifth place of decimals = 0.003". The center of the plate is near $x = 14$, $y = 14$.

Plate constants were then calculated in the usual way, by the formulæ

$$\Delta x = ax + by + c$$

$$\Delta y = dx + ey + f$$

These were applied, and the residuals $\Delta_1 x$, $\Delta_1 y$ converted into arc are as follows:

TABLE XII.—*Check plates, residuals.*

Star.	q_1-a_1 .		w_1-b_1 .		s_1-c_1 .		r_1-d_1 .		v_1-e_1 .		Mean.	
	$\Delta_1 x$.	$\Delta_1 y$.	$\Delta_1 x$.	$\Delta_1 y$.	$\Delta_1 x$.	$\Delta_1 y$.	$\Delta_1 x$.	$\Delta_1 y$.	$\Delta_1 x$.	$\Delta_1 y$.	$\Delta_1 x$.	$\Delta_1 y$.
1.....	-.02	-.02	+.29	-.34	+.02	-.07	-.03	+.22	+.49	+.01	+.15	-.04
2.....	+.39	+.15	+.16	+.14	+.69	.00	+.69	-.29	+.10	-.23	+.41	-.05
4.....	-.14	-.04	-.16	+.09	-.38	-.12	-.02	-.37	-.54	+.12	-.25	-.06
5.....	-.08	+.35	.....	.....	+.25	+.19	-.21	-.21	.....	-.01	-.01	+.08
6.....	-.06	-.10	-.28	+.27	-.09	+.14	-.10	+.12	+.15	+.49	-.08	+.18
7.....	-.06	-.28	-.10	-.16	-.74	-.09	-.31	+.02	-.39	-.12	-.32	-.13
8.....	-.30	+.34	.....	.....	.....	.....	.....	.....	-.38	-.68	-.34	-.17
10.....	-.02	-.10	-.21	+.52	-.15	+.16	+.08	+.25	-.08	+.34	-.08	+.23
11.....	-.46	-.01	-.13	-.22	-.13	+.11	-.13	+.71	+.30	-.28	-.11	+.06
12.....	+.16	-.14	+.13	-.04	+.19	-.06	+.17	-.09	-.13	+.08	+.10	-.05
13.....	+.59	-.12	+.32	-.26	+.24	-.25	-.13	-.38	+.48	+.28	+.32	-.15

The mean residual without regard to sign is $\pm 0.21''$, from which the probable error of a determination of Δx or Δy is $\pm 0.22''$.

Star 7 is much the brightest. Stars 1, 6, 11, 13 are rather bright. Stars 2, 4, 10, 12 are fainter and more comfortable to measure. Stars 5 and 8 are very faint. Arcturus is on the plates but is much too bright to measure. No measures have been rejected.

The determination of the deflection on the eclipse plates is based on the declinations (y), and the last column of Table XII shows that on the check plates the y comparisons are free from any serious systematic error.

Star 7 is of particular interest; its position near the center of the field corresponds to that of α_1, α_2 Tauri in the eclipse field, from which the greatest deflection is expected. The images (which are not quite round) have the same characteristic shape. Further, the brightness of No. 7 corresponds with but exaggerates the brightness of α_1 Tauri, which is the brightest star in the eclipse field. It is therefore a valuable check to find that its systematic error in declination is insignificant compared with the displacement (of the order of $1''$) afterwards found for α_1 and α_2 Tauri.

The systematic errors in right ascension are larger (probably through imperfect driving of the clock). They may affect the displacement indirectly through the orientation constant, but with much reduced effect. Allowing for this reduction in importance there appears to be nothing to trouble about.

The primary purpose of the check plates is thus fulfilled. They show that photographs of a check field of stars taken at Oxford and Principe show none of the displacements which are exhibited by the photographs of the eclipse field taken under precisely similar instrumental conditions. The inference is that the displacements in the latter case can only be attributed to presence of the eclipsed sun in the field.

33. We turn now to the differences of scale between Oxford and Principe, which are given by the plate constants a, b, d, e determined from the measures. As determined these include the effects of differential refraction and aberration. The latter corrections were calculated for each plate by the usual formulæ and applied so as to determine the corrected plate constants a', b', d', e' free from differential refraction and aberration. Due allowance was made for the change in the coefficient of refraction owing to the difference of barometer and temperature (about 40°) between Oxford and Principe. The results are as follows (in units of the fifth place of decimals) :

TABLE XIII.—*Check plates, plate constants.*

Comparison.	Uncorrected.				Corrected.				
	<i>a.</i>	<i>b.</i>	<i>d.</i>	<i>e.</i>	<i>a'</i>	<i>b'</i>	<i>d'</i>	<i>e'</i>	<i>b'+d'</i>
g_1-a_1	+32.7	+101.0	- 87.8	+58.2	+32.7	+ 98.4	- 90.4	+32.1	+ 8.0
w_1-b_1	+26.2	- 16.0	+ 25.9	+53.6	+30.4	- 22.5	+ 19.4	+31.4	- 3.1
s_1-c_1	+31.5	+192.5	-173.5	+64.8	+35.8	+182.6	-183.4	+42.1	- 0.8
r_1-d_1	+28.2	+165.0	-146.8	+69.8	+32.1	+157.8	-154.0	+45.0	+ 3.8
v_1-e_1	+21.6	- 76.2	+ 70.6	+61.4	+25.2	- 80.5	+ 66.3	+35.7	-14.2
Mean.....					+31.2			+37.3	- 1.3

The sign of the results shows that the scale of the photographs is larger at Principe than at Oxford; in fact, the focus must have been set about 1.2 millimeters farther out (apart from any change of length compensated by expansion of the photographic plates). As the error in focusing was probably not more than 0.5 millimeter, the greater part of this shift must be due to the focal length of the lens combination increasing with temperature more rapidly than the linear expansion of the glass.

If the only difference were a change of focal length, we should have $a'=e'$. There is a fairly strong indication that e' is greater than a' . This is no doubt due to a change in the definition caused by the cœlostator mirror or by a shift of the object-glass lenses on the journey; and as it will presumably affect the eclipse plates in the same way, it is best to adopt the values of a' and e' as determined, rather than to take a mean. In so doing we shall at any rate not exaggerate the displacement, which depends mainly on the y measures and is reduced by adopting too large a value of e' .³

The difference $b'-d'$ merely gives the relative orientation of the two plates as placed face to face. The sum $b'+d'$ practically vanishes, as it should do. However, for consistency we adopt the small value found.

From the internal discordances of our determination of e' (the most important of these constants) the probable error of the mean is ± 2.1 . This, as shown later, will cause a probable error of our final determination of the deflection, reduced to the limb of the sun, of amount $\pm 0.14''$, affecting all determinations systematically. Errors in the other constants have much smaller influence.

THE ECLIPSE PLATES.

34. The eclipse plates from K to S show no star images. After that the cloud lightened somewhat, and some images appear on the

³ It happens that it is also reduced, but to a less extent, by using too small a value of a' .

remaining plates. The sky was never clear and nothing fainter than 5.5^m is shown. The cloud was variable in different parts of the plate, so that the brightness of the images varies erratically and the diffusion is also variable.

In order to obtain results of any weight the stars 4 and 3 (α_1 and α_2 Tauri), which theoretically should be strongly displaced, must be shown. They appear on all plates from T to Z, and being near the center of the field have good images. They are relatively rather faint on plate U, but are bright on the other plates. The appearance of the remaining stars is as follows:

Plate T.—6 bright; 10 faint.

Plate U.—6, 10 very bright; 11 faint.

Plate V.—6 bright; 10 fair.

Plate W.—5, 6 good; 10 diffused.

Plate X.—5, 6, 11 good.

Plate Y.—5, 6, 11 faint, diffused; 12 very faint.

Plate Z.—5, 6, 11 faint, diffused.

The possibility of a determination of deflection practically depends on the appearance of star 5. The relative displacement of 5 and 3 is on Einstein's theory, $1.2''$ in the y -coordinate. Further, the x -measures of 5 are needed for a really good determination of the orientation. Star 11 can scarcely take its place. It is true that the relative displacement is then $0.8''$; but the orientation affects this with a much larger factor, and the orientation is badly determined in the absence of star 5.

Accordingly plates W and X are the only ones likely to give a trustworthy result. X is somewhat the better plate of the two.¹⁰ Measures have been made of the faint diffused images on plates Y and Z; but, as might have been expected, they are hopelessly discordant and can not be reconciled by any adopted value of the deflection.

35. We give the measures of plates X and W in detail. Both comparisons of X were measured at Principe a few days after the eclipse. Plate W, which was not developed until after the return of the expedition, was measured at Cambridge on August 22–23.¹¹

¹⁰ Plate X has also the merit of a short exposure, 3 seconds. We should mistrust the x -measures of a long exposure with variable cloud and imperfect guiding, because there is nothing to show that the images of the different stars are formed at the same time.

¹¹ Of the comparisons of check plates, $w_1 - b_1$ was measured on August 20, and the others about the end of September. Previous measures had been made at Principe with three earlier check plates taken on the night of May 16; but a slight change of adjustment of tilt was made the following day (thereafter it remained unaltered until the eclipse), and the small change of focus allowed for in the comparisons. These furnished a provisional scale which was used to obtain preliminary results. Afterwards the measurement of check plates was undertaken in a more systematic way, using later plates about which no doubt could arise, and giving the results printed above. No change of any importance was found; the final value for the deflection at the limb was reduced by $0.4''$ compared with the provisional value, but this was mainly due to the adoption of separate values of α' and ϵ' instead of adopting the mean, and to recalculation of the differential refraction and aberration.

PLATE X.

(1) *Comparison with Oxford plate G₁.*—The differential refraction for all the eclipse plates is

$$a = -46.5, \quad b, d = +8.2, \quad e = -27.0,$$

the differential aberration being zero.

For the comparison plate G₁

$$a = -19.1, \quad b, d = +0.7, \quad e = -28.3.$$

Hence for X—G₁

$$a = -27.4, \quad b, d = +7.5, \quad e = +1.3.$$

To these must be added the terms representing change of scale, determined from the check plates (Table XIII.), viz.

$$a = +31.2, \quad b, d = -0.6, \quad e = +37.3.$$

Hence the whole difference X—G₁ is given by

$$a = +3.8, \quad b, d = +6.9, \quad e = +38.6.$$

The first step is to take the measured differences Δx , Δy , and take out the parts $ax + by$, $dx + ey$, due to these terms, leaving the corrected differences $\Delta_1 x$, $\Delta_1 y$.

$\Delta_1 x$ and $\Delta_1 y$ contain (1) the Einstein displacement, if any and (2) the unknown relative orientation of the plates giving rise to terms of the form, $\Delta x = +\theta y$, $\Delta y = -\theta x$. These two parts could be separated by a least-squares solution, but in view of the poor quality of the material it seems better to adopt a method which keeps a better check on possible discordances and shows more clearly what is happening. The Einstein displacement in x is small, and we might perhaps neglect it altogether in determining θ from the x -measures. However, it is clear from preliminary trials that a displacement exists—whether the half or the full Einstein displacement. Hence if we take out three-quarters of the full Einstein displacement ($\frac{3}{4}E_x$) we divide the already slight effect by 4, and at the same time deal fairly between the two hypotheses.¹² The residuals $\Delta_2 x$ result.

From the equations $\Delta_2 x = c + \theta y$ we determine by least squares the orientation θ , which is found to be $+163$. Removing the term $163y$ we obtain the residuals $\Delta_3 x$.

Turning to $\Delta_1 y$, we correct for the orientation by taking out the term $-163x$, leaving $\Delta_3 y$. These values should agree for all the stars, except for the displacement and the accidental error.

¹² The smaller the displacement provisionally assumed for x , the larger is the displacement ultimately found from y (see p. 171).

Denoting the value of the displacement at 50' (or 10 réseau-intervals) from the center of the sun by x , the y -displacements of the various stars will be α_y , where α_y has the values tabulated below. We can therefore obtain x , by solving by least-squares the equations

$$\Delta_s y = f + x \alpha_y.$$

The radius of the sun during the eclipse was 15.78'. Hence the full Einstein displacement of 1.75'' corresponds to 0.55'' at 50' distance, or, in our units of 0.003'', $x = 184$. It is easily seen that the value is somewhere near this, and it is therefore easier and more instructive to take out $E_y = 184\alpha_y$, and determine the correction to x from the residuals $\Delta_s y$. We also remove the mean of $\Delta_s y$ obtaining the final residuals.

The normal equations corresponding to equations of condition

$$\text{residual} = \delta f + \alpha_y \delta x$$

are found to be

$$\begin{aligned} 5\delta f + 2.83\delta x &= -1 \\ 2.83\delta f + 4.83\delta x &= +64 \end{aligned}$$

whence

$$\begin{aligned} 3.23\delta x &= +64, \\ \delta x &= +20. \end{aligned}$$

An increase of 20 on 184 corresponds to an increase of 0.19'' on 1.75''. Hence the resulting deflection at the limb is 1.94.''

Since the full deflection is indicated we complete the results for x by taking out the remaining $\frac{1}{2}E_x$, obtaining $\Delta_s x$, and then tabulate the residuals from the mean values—5942.

The successive steps are shown below:

Star.	x .	Δx .	3-8x.	6-9y.	$\Delta_1 x$.	$\frac{1}{2}E_x$.	$\Delta_s x$.	+163y.	$\Delta_s x$.	$\Delta_s x$.	Resid. (unit=0.003'').
11.....	1.39	-3,916	5	86	-4,007	-76	-3,931	2,021	-5,952	-5,927	+ 15
5.....	12.40	-5,518	47	20	-5,585	-79	-5,506	478	-5,984	-5,958	- 16
4.....	17.34	-2,869	66	129	-3,064	-54	-3,010	3,051	-6,061	-6,043	-101
3.....	17.48	-2,924	66	121	-3,111	-69	-3,042	2,869	-5,911	-5,888	+ 54
6.....	19.87	-1,568	75	172	-1,815	+ 3	-1,818	4,075	-5,893	-5,894	+ 48

Star.	y .	Δy .	6-9x.	38-6y.	$\Delta_1 y$.	-163x.	$\Delta_s y$.	E_y .	$\Delta_s y$.	α_y .	Resid.
11.....	12.40	6,398	10	479	5,909	- 227	6,136	+ 6	6,130	+0.03	+ 5
5.....	2.93	4,121	86	113	3,922	-2,021	5,943	-127	6,070	-0.69	- 55
4.....	18.72	4,512	120	723	3,670	-2,826	6,496	+234	6,262	+1.27	+137
3.....	17.60	4,236	121	679	3,436	-2,849	6,285	+272	6,013	+1.48	-112
6.....	24.99	4,148	137	965	3,046	-3,239	6,285	+136	6,149	+0.74	+ 24

(2) *Comparison with Oxford plate H₁.*—The reductions are similar and are given in a rather more condensed form below. The theoretical plate constants are

$$a = +3.8, \quad b, d = +8.3, \quad e = +38.6.$$

Star.	$\Delta x.$	$\Delta_1 x.$	$\Delta_2 x.$	+10y.	$\Delta_3 x.$	$\Delta_4 x.$	Resid.
11.....	7,290	7,182	7,258	124	7,134	7,159	+235
5.....	6,751	6,680	6,759	29	6,730	6,756	-168
4.....	7,126	6,905	6,959	187	6,772	6,790	-134
3.....	7,320	7,108	7,177	176	7,001	7,024	+100
6.....	7,429	7,147	7,144	250	6,894	6,893	-31

Star.	$\Delta y.$	$\Delta_1 y.$	-10x.	$\Delta_2 y.$	E _y .	$\Delta_3 y.$	Resid.
11.....	1,586	1,095	-14	1,109	+6	1,103	+172
5.....	858	642	-124	766	-127	893	-38
4.....	1,881	1,015	-173	1,188	+234	954	+23
3.....	1,785	961	-175	1,136	+272	864	-67
6.....	1,909	779	-199	978	+136	842	-89

The normal equations are

$$\begin{aligned} 5\delta f + 2.83\delta x &= +1 \\ 2.83\delta f + 4.83\delta x &= -105 \end{aligned}$$

whence

$$\begin{aligned} 3.23\delta x &= -105, \\ \delta x &= -33. \end{aligned}$$

The corresponding deflection at the limb is

$$1.75'' - 0.31'' = 1.44''$$

PLATE W.

Although the exposure was only 10 seconds the images have jumped in right ascension, so that the appearance is dumb-bell shaped. They are, however, symmetrical, so that fair measures of x can be made; the y measures on which the result chiefly depends are unaffected. Star 10 is very diffused in right ascension.

(1) *Comparison with Oxford plate D₁.*—Theoretical plate constants

$$a = +4.9, \quad b, d = +6.5, \quad e = +39.7.$$

Star.	$x.$	$\Delta x.$	$\Delta_1 x.$	$\frac{1}{2}E_x.$	$\Delta_2 x.$	+91y.	$\Delta_3 x.$	$\Delta_4 x.$	Resid.
5.....	12.40	2,450	2,370	-79	2,449	267	2,182	2,208	+40
4.....	17.34	3,948	3,741	-54	3,735	1,704	2,091	2,109	-59
3.....	17.48	3,834	3,634	-69	3,703	1,602	2,101	2,124	-44
6.....	19.87	4,525	4,266	+3	4,263	2,275	1,983	1,987	-181
10.....	22.60	5,199	4,911	+17	4,894	2,476	2,418	2,412	+244

Star.	y .	Δy .	$\Delta_1 y$.	$-91x$.	$\Delta_2 y$.	E_y .	$\Delta_3 y$.	α_y .	Resid.
5.....	2.93	5,320	5,123	-1,123	6,251	-127	6,378	-0.69	+ 70
4.....	18.72	5,745	4,889	-1,578	6,467	+234	6,233	+1.27	- 75
3.....	17.60	5,911	5,098	-1,591	6,689	+272	6,417	+1.48	+109
6.....	24.99	5,628	4,507	-1,808	6,315	+136	6,179	+0.74	-129
10.....	27.21	5,616	4,389	-2,057	6,446	+114	6,332	+0.62	+ 24

Normal equations

$$\begin{aligned} 5\delta f + 3.42\delta x &= -1 \\ 3.42\delta f + 5.21\delta x &= -62 \end{aligned}$$

whence

$$\begin{aligned} 2.87\delta x &= -61 \\ \delta x &= -21. \end{aligned}$$

Hence deflection at the limb is

$$1.75'' - 0.20'' = 1.55''.$$

(2) Comparison with Oxford Plate I₂.—Theoretical plate constants

$$a = +4.0, \quad b, d = +9.1, \quad e = +38.8.$$

Star.	Δx .	$\Delta_1 x$.	$\Delta_2 x$.	$-30y$.	$\Delta_3 x$.	$\Delta_4 x$.	Resid.
5.....	5,050	4,973	5,052	- 88	5,140	5,166	+ 46
4.....	4,732	4,493	4,517	-562	5,109	5,127	+ 7
3.....	4,622	4,392	4,461	-528	4,989	5,012	-108
6.....	4,635	4,329	4,326	-750	5,076	5,075	- 45
10.....	4,764	4,426	4,409	-816	5,225	5,219	+ 90

Star.	Δy .	$\Delta_1 y$.	$+30x$.	$\Delta_2 y$.	E_y .	$\Delta_3 y$.	Resid.
5.....	-6,824	-7,051	372	-7,423	-127	-7,296	- 15
4.....	-5,751	-6,635	520	-7,155	+234	-7,389	-108
3.....	-5,609	-6,451	524	-6,975	+272	-7,247	+ 34
6.....	-5,425	-6,576	596	-7,172	+136	-7,308	- 27
10.....	-5,109	-6,371	678	-7,049	+114	-7,163	+118

Normal equations

$$\begin{aligned} 5\delta f + 3.42\delta x &= +2 \\ 3.42\delta f + 5.21\delta x &= -24 \end{aligned}$$

whence

$$\begin{aligned} 2.87\delta x &= -25 \\ \delta x &= -9. \end{aligned}$$

Hence deflection at the limb is

$$1.75'' - 0.08'' = 1.67''.$$

PLATE U.

Comparison with Oxford Plate K₂.—Since Plate U shows some good images it has been examined, although owing to the absence of star 8 the weight is small. The measures were made at Principe.

Theoretical plate-constants

$$a = +2.8, \quad b.d = +8.9, \quad e = +37.7.$$

Star.	x .	Δx .	$\Delta_1 x$.	+240 y .	E_x .	Δx .	Resid.
11.....	1.39	2,905	2,791	2,976	-101	-84	-147
4.....	17.34	4,508	4,292	4,493	-72	-129	-192
3.....	17.48	4,626	4,420	4,224	-92	+283	+225
6.....	19.87	6,270	5,992	5,998	+4	-10	-73
10.....	22.60	7,110	6,805	6,530	+23	+252	+189

Star.	y .	Δy .	$\Delta_1 y$.	-240 x .	E_y .	Δy .	Resid.
11.....	12.40	9,026	8,547	-334	+6	8,875	-94
4.....	18.72	5,846	4,986	-3,162	+234	8,914	-55
3.....	17.60	5,985	5,165	-4,195	+272	9,089	+120
6.....	24.99	5,458	4,339	-4,769	+136	8,972	+3
10.....	27.21	4,911	3,684	-5,424	+114	8,994	+25

In this case it is not possible to determine the orientation with sufficient accuracy from the x -measures; the value here applied is an arbitrary preliminary value. We accordingly make a least-squares solution from both x - and y -residuals to determine the correction to the orientation, $\delta\theta$, as well as δc , δf , and δx .

The result is

$$\delta\theta = +2, \quad \delta x = +121.$$

This gives the deflection 2.90".

The probable error is, however, $\pm 0.87''$, so that the result is practically worthless. Further, it is much more likely to be affected by systematic error than the previous results.

The large probable error is partly due to the large residuals which are greater than in the previous measures; in particular star 3 is unduly faint. If the same accuracy had been obtained, the theoretical weight would have been half that of Plates W and X; but having regard to possible systematic error, probably a quarter weight would more nearly represent the true value.

This determination is ignored in the subsequent discussion.

36. It is easy to calculate the effects of any errors in the adopted scale, orientation, etc., on the final result (deflection at the limb). We give some illustrations.

An error in the adopted scale of y of 10 units (in the fifth place of decimals) would lead to an error 0.68" in the result from either plate. Thus the probable error ± 2.1 in the determination of e' gives a

probable error $\pm 0.14''$ in the final result; or, if we adopted the largest (rather discordant) value found for e' instead of the mean, we should reduce the result by $0.52''$.

An error of 10 units in the orientation gives an error in the result of $0.45''$ for plate X, and $0.22''$ for plate W. It is therefore of less importance, and further it is not likely to be systematic.

Errors in the measurement of x only affect the result through the orientation. For plate X, a probable error of $\pm 0.20''$ in the x -measures would give an error ± 4.0 in the orientation, leading to an error $\pm 0.18''$ in the result; whereas an error of the same magnitude in the y -measures gives directly an error $\pm 0.35''$ in the result. For plate W, the probable error of $\pm 0.20''$ in x gives an error ± 3.5 in the orientation and $\pm 0.08''$ in the result, compared with $\pm 0.38''$ for similar inaccuracy in y . It is particularly fortunate that the x -measures are so unimportant for plate W, because, as already mentioned, the images trailed on that plate.

Finally, it will be remembered that in order not to commit ourselves to the Einstein hypothesis prematurely we neglected the correction $4E_x$ in determining the orientation. This will make a difference of $0.029''$ in the results from plate W and $0.092''$ from plate X. The effect is that the deduced deflection needs to be decreased, and the mean correction $-0.06''$ should be applied to the mean result obtained or rather to make the adopted deflection for x consistent with the deduced value from y , the correction needed is $-0.04''$.

DISCUSSION OF THE RESULTS.

37. The four determinations from the two eclipse plates are

X-G	-----	1.94''
X-H	-----	1.44''
W-D	-----	1.55''
W-I	-----	1.67''

Giving a mean of ----- 1.65''

They evidently agree with Einstein's predicted value $1.75''$.

The residuals¹³ in the separate comparisons reduced to arc are as follows. They do not appear to show any special peculiarities:

Star.	x -residuals.					y -residuals.				
	G.	H.	D.	I.	Mean.	G.	H.	D.	I.	Mean.
11.....	"	"	"	"	"	"	"	"	"	"
5.....	+0.04	+0.70	-----	-----	-----	+0.01	+0.52	-----	-----	-----
1.....	-0.05	-0.50	+0.12	+0.14	-0.07	-0.16	-0.11	+0.21	-0.04	-0.02
4.....	-0.30	-0.40	-0.18	+0.02	-0.21	+0.41	+0.07	-0.22	-0.32	-0.02
3.....	+0.16	+0.30	-0.13	-0.32	0.00	-0.34	-0.20	+0.33	+0.10	-0.03
6.....	+0.14	-0.09	-0.54	-0.13	-0.16	+0.07	-0.27	-0.39	-0.08	-0.17
10.....	-----	-----	+0.73	+0.27	-----	-----	-----	+0.07	+0.35	-----

¹³ The residuals refer to the theoretical deflection $1.75''$, not the deduced deflections.

The average y -residual is $\pm 0.22''$, which gives a probable error for y of $\pm 0.21''$. It is satisfactory that this agrees so nearly with the probable error ($\pm 0.22''$) of the check plates, showing that the images are of about the same degree of difficulty and therefore presumably comparable. The probable error of x is $\pm 0.25''$, but we are not so much concerned with this.

The weight of the determination of $\Delta\kappa$ is about 3 (strictly 3.23 for plate X and 2.87 for plate W). The probable error of κ is therefore $\pm 0.12''$, which corresponds to a probable error of $\pm 0.38''$ in the final values of the deflection.

As the four determinations involve only two eclipse plates and are not wholly independent, and further small accidental errors may arise through inaccurate determination of the orientation, the probable error of our mean result will be about $\pm 0.25''$. There is further the error of $\pm 0.14''$ affecting all four results equally, arising from the determination of scale. Taking this into account, and including the small correction $-0.04''$ previously mentioned, our result may be written $1.61'' \pm 0.30''$.

It will be seen that the error deduced in this way from the residuals is considerably larger than at first seemed likely from the accordance of the four results. Nevertheless the accuracy seems sufficient to give a fairly trustworthy confirmation of Einstein's theory, and to render the half-deflection at least very improbable.

38. It remains to consider the question of systematic error. The results obtained with a similar instrument at Sobral are considered to be largely vitiated by systematic errors. What ground then have we—apart from the agreement with the far superior determination with the 4-inch lens at Sobral—for thinking that the present results are more trustworthy?

At first sight everything is in favor of the Sobral astrographic plates. There are 12 stars shown against 5, and the images, though far from perfect, are probably superior to the Principe images. The multiplicity of plates is less important, since it is mainly a question of systematic error. Against this must be set the fact that the five stars shown on plates W and X include all the most essential stars; stars 3 and 5 give the extreme range of deflection, and there is no great gain in including extra stars which play a passive part. Further, the gain of nearly two extra magnitudes at Sobral must have meant over-exposure for the brighter stars, which happen to be the really important ones; and this would tend to accentuate systematic errors, whilst rendering the defects of the images less easily recognized by the measurer. Perhaps, therefore, the cloud was not so unkind to us after all.

Another important difference is made by the use of the extraneous determination of scale for the Principe reductions. Granting its

validity, it reduces very considerably both accidental and systematic errors. The weight of the determination from the five stars with known scale is more than 50 per cent greater than the weight from the 12 stars with unknown scale. Its effect as regards systematic error may be seen as follows. Knowing the scale, the greatest relative deflection to be measured amounts to $1.2''$ on Einstein's theory; but if the scale is unknown and must be eliminated, this is reduced to $0.67''$. As we wish to distinguish between the full deflection and the half deflection, we must take half these quantities. Evidently with poor images it is much more hopeful to look for a difference of $0.6''$ than for $0.3''$. It is, of course, impossible to assign any precise limit to the possible systematic error in interpretation of the images by the measurer; but we feel fairly confident that the former figure is well outside possibility.

A check against systematic error in our discussion is provided by the check plates, as already shown. Its efficacy depends on the similarity of the images on the check plates and eclipse plates at Principe. Both sets are fainter than the Oxford images with which they are compared, the former owing to the imperfect driving of the cölostat, which made it impossible to secure longer exposures, the latter owing to cloud. Both sets have a faint wing in declination, but this is separated by a slight gap from the true images, and, at least on the plates measured, the wing can be distinguished and ignored. The images on plates W and X are not unduly diffused except for No. 10 on plate W. Difference in quality between the eclipse images and the Principe check images is not noticeable, and is certainly far less than the difference between the latter and the Oxford images; and, seeing that the latter comparison gives no systematic error in y , it seems fair to assume that the comparison of the eclipse plates is free from systematic error.

The writer must confess to a change of view with regard to the desirability of using an extraneous determination of scale. In considering the program it had seemed too risky a proceeding, and it was thought that a self-contained determination would receive more confidence. But this opinion has been modified by the very special circumstances at Principe; and it is now difficult to see that any valid objection can be brought against the use of the scale.

The temperature at Principe was remarkably uniform and the extreme range probably did not exceed 4° during our visit—including day and night, warm season and cold season. The temperature ranged generally from $77\frac{1}{2}^{\circ}$ to $79\frac{1}{2}^{\circ}$ in the rainy season, and about 1° colder in the cool gravana. All the check plates and eclipse plates were taken within a degree of the same temperature, and there was, of course, no perceptible fall of temperature preceding totality. To avoid any alteration of scale in the daytime the telescope tube and

object glass were shaded from direct solar radiation by a canvas screen; but even this was scarcely necessary, for the clouds before totality provided a still more efficient screen, and the feeble rays which penetrated could not have done any mischief. A heating of the mirror by the sun's rays could scarcely have produced a true alteration of scale though it might have done harm by altering the definition; the cloud protected us from any trouble of this kind. At the Oxford end of the comparison the scale is evidently the same for both sets of plates, since they were both taken at night and intermingled as regards date.

It thus appears that the check scale is legitimately applicable to the eclipse plates. But the method may not be so satisfactory at future eclipses, since the particular circumstances at Principe are not likely to be reproduced. As regards other sources of systematic error, our chief guaranty lies in the comparatively large amount of the deflection to be measured, and the test satisfied by the check plates that photographs of another field under similar conditions show no deflections comparable with those here found.

V. GENERAL CONCLUSIONS.

39. In summarizing the results of the two expeditions, the greatest weight must be attached to those obtained with the 4-inch lens at Sobral. From the superiority of the images and the larger scale of the photographs it was recognized that these would prove to be much the most trustworthy. Further, the agreement of the results derived independently from the right ascensions and declinations, and the accordance of the residuals of the individual stars (p. 152) provides a more satisfactory check on the results than was possible for the other instruments.

These plates gave—

From declinations.....	1.94"
From right ascensions.....	2.06"

The result from declinations is about twice the weight of that from right ascensions, so that the mean result is $1.98''$, with a probable error of about $\pm 0.12''$.

The Principe observations were generally interfered with by cloud. The unfavorable circumstances were, perhaps, partly compensated by the advantage of the extremely uniform temperature of the island. The deflection obtained was $1.61''$.

The probable error is about $\pm 0.30''$, so that the result has much less weight than the preceding.

Both of these point to the full deflection $1.75''$ of Einstein's generalized relativity theory, the Sobral results definitely, and the Principe results perhaps with some uncertainty. There remain the Sobral astrographic plates, which gave the deflection $0.93''$, discordant by

an amount much beyond the limits of its accidental error. For the reasons already described at length not much weight is attached to this determination.

It has been assumed that the displacement is inversely proportional to the distance from the sun's center, since all theories agree on this, and, indeed, it seems clear from considerations of dimensions that a displacement, if due to gravitation, must follow this law. From the results with the 4-inch lens, some kind of test of the law is possible though it is necessarily only rough. The evidence is summarized in the following table and diagram, which show the radial displacement of the individual stars (mean from all the plates) plotted against the reciprocal of the distance from the center. The displacement according to Einstein's theory is indicated by the heavy line, according to the Newtonian law by the dotted line, and from these observations by the thin line.

Radial displacement of individual stars.

Star.	Calcula- tion.	Observa- tion.
	"	"
11.....	0.32	0.20
10.....	0.33	0.32
6.....	0.40	0.56
5.....	0.53	0.54
4.....	0.75	0.84
2.....	0.85	0.97
3.....	0.88	1.02

Thus the results of the expeditions to Sobral and Principe can leave little doubt that a deflection of light takes place in the neighborhood of the sun and that it is of the amount demanded by Einstein's generalized theory of relativity, as attributable to the sun's gravita-

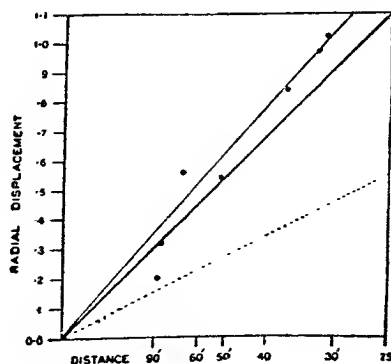


FIG. 2.

tional field. But the observation is of such interest that it will probably be considered desirable to repeat it at future eclipses. The unusually favorable conditions of the 1919 eclipse will not recur, and it will be necessary to photograph fainter stars, and these will probably be at a greater distance from the sun. This can be done with such telescopes as the astrographic, with the object glass stopped down to 8 inches, if photographs of the same high quality are obtained as in regular stellar work. It will probably be best to discard the use of cœlostát mirrors. These are of great convenience for photographs of the corona and spectroscopic observations, but for work of precision of the high order required, it is undesirable to introduce complications, which can be avoided, into the optical train. It would seem that some form of equatorial mounting (such as that employed in the eclipse expeditions of the Lick Observatory) is desirable.

In conclusion, it is a pleasure to record the great assistance given to the expeditions from many quarters. Reference has been made in the course of the paper to some of these. Especial thanks are due to the Brazilian Government for the hospitality and facilities accorded to the observers in Sobral. They were made guests of the Government, who provided them with transport, accommodation, and labor. Doctor Morize, director of the Rio Observatory, acting on behalf of the Brazilian Government, made most complete arrangements for the expedition, and in this way contributed materially to its success.

On behalf of the Principe expedition, special thanks are due to Sr. Jeronymo Carneiro, who most hospitably entertained the observers and provided for all their requirements, and to Sr. Atalaya, whose help and friendship were of the greatest service to the observers in their isolated station.

We gratefully acknowledge the loan for more than six months of the astrographic object glass of the Oxford University Observatory. We are also indebted to Mr. Bellamy for the check plates he obtained in January and February.

Thanks are due to the Royal Irish Academy for the loan of the 4-inch object glass and 8-inch cœlostát.

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WIRELESS TELEPHONY.¹

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[With 6 plates.]

FUNDAMENTAL REQUIREMENTS.

The development of wireless telephony dates back almost as far as the original conception of the use of electromagnetic waves for wireless telegraphy. The practical utilization of this method of communication is, however, a matter of comparatively recent date as contrasted with the much longer period during which wireless telegraphy has been a practical accomplishment. This delay in the successful utilization of wireless telephony is due to certain differences in the fundamental requirements as compared with those for the telegraph. These differences and the manner in which the particular difficulties incident to the successful accomplishment of wireless telephony have been overcome will be explained in detail in succeeding paragraphs.

Broadly speaking, the principal difference between wireless telephony and wireless telegraphy lies in the form of the signal which has to be transmitted, telegraph signals being obviously far simpler in the wave-form of the signal current than are telephone signals. The fundamental requirement is in either case that the form of the received signal shall faithfully reproduce the form of the transmitted signal, whether due to the opening and closing of a telegraph key or the vibrations of a telephone transmitter diaphragm.

The essential units required in a complete wireless telephone system may be grouped into the transmitting and the receiving elements. The receiving elements, being in no respect different from those required in wireless telegraphy, will not be described at this point. The transmitting elements differ, however, in many respects and comprise the following essential units:

A radio frequency generator.

A modulator for controlling the radio frequency current.

An antenna for radiating the electromagnetic waves produced by the radio frequency current.

¹ Presented at a joint meeting of the electrical section and the Philadelphia section, American Institute of Electrical Engineers, held Thursday, Oct. 30, 1919. Reprinted by permission from the Journal of the Franklin Institute, January, 1920.

The particular characteristics of these various units are described in detail hereinafter.

Wireless telephony is subject to certain particular limitations in the same way as wireless telegraphy, notably that of interference due to atmospheric electricity or radio signals foreign to the desired signal.

HISTORICAL SUMMARY.

The first requirement for any wireless telephone station is a source of radio frequency current whose amplitude from cycle to cycle remains constant, except when varied by the modulation imposed upon it by the voice current. If variations in its amplitude occur, due to other causes, these variations will introduce disturbances which will cause the system to be deficient in the effective transmission of speech. It is at once evident that the original source of radio frequency current used in wireless telegraphy, namely, the oscillatory discharge of a condenser supplied with energy from a low frequency source, is entirely unsuited to the purposes of wireless telephony.

With the development of the Poulsen arc the first successful attempts at radio telephony were begun. These attempts involved the second factor in a wireless telephone station, namely, that of modulating the radio frequency current in accordance with the currents supplied by a telephone transmitter. The early attempts to accomplish this modulation, by means of microphones inserted directly in the antenna circuit or coupled to the circuit in various manners, were largely unsuccessful, due to the limitations of the microphone devices, such as the low current capacity and the small range of variation of resistance.

A second source of radio frequency current is the high frequency alternator, which has been developed in various forms and which has been likewise used with limited success for wireless telephone transmission. The same lack of a suitable modulating device handicapped the use of the high frequency alternator until the advent of the audion or vacuum tube. The characteristics of the vacuum tube have been fully described in many recent publications, and will be discussed in this paper only in so far as these characteristics are directly applicable to the problems of wireless telephony. It will be seen from this subsequent discussion that the vacuum tube possesses in a remarkable manner the precise characteristics required for the generation and modulation of radio frequency current for low power wireless telephone stations, and for the detection and amplification of radio signals of any character whatsoever. Its influence on the art of wireless telephony may well be compared with the influence of the gas engine on aviation.

VACUUM TUBE.

The requirements of a radio frequency generator may be grouped as follows:

The desired frequency may range roughly between the values of 15,000 and 6,000,000 cycles per second.

The frequency for any particular generator may be required to vary over a considerable range, in some cases as much as several octaves. In other cases, a single value of frequency is sufficient.

The frequency when set at a particular value should remain substantially unaffected by ordinary changes in the physical or electrical conditions associated with the station.

The current delivered by the generator should approximate a sine wave as closely as possible.

The required output for different classes of stations may vary from less than one watt to several hundred kilowatts.

The efficiency of the generator should be reasonably high though not necessarily comparable with the efficiencies obtained from ordinary types of generators.

When used as an oscillator or radio frequency generator associated with properly designed circuits, the vacuum tube will meet all of these requirements, with the exception that the power output of vacuum tubes as at present constructed is limited to not more than a few hundred watts per tube.

The requirements of a modulator for radio telephony may be grouped as follows:

The modulator should be actuated by the current from an ordinary microphone telephone transmitter or its equivalent.

The modulator should faithfully reproduce, in its effect upon the radio frequency current, the wave-form of the telephone or speech current.

The modulator should be capable of almost completely modulating the output of radio frequency generators whose power outputs may cover the range indicated above.

These requirements are fulfilled to a remarkable extent by the vacuum tube used in properly designed circuits.

Although the vacuum tube was invented in 1906, its development into a sufficiently practical form to be useful for wireless telephony was comparatively slow. This development was greatly accelerated, beginning in 1912, when the American Telephone & Telegraph Co. became interested in the vacuum tube for use in telephone repeaters. Rapid improvements were made in the design and construction of vacuum tubes, and at the same time experiments were conducted look-

ing to the use of the vacuum tube in wireless telephone apparatus. As a result of these experiments, the transmission of speech from Washington, D. C., to Paris and Honolulu by wireless telephone occurred during the year 1915. In these experiments the vacuum tube was used as a radio frequency generator, a modulator, a detector, and amplifier.

The possibilities of the vacuum tube for wireless telephony having been partly disclosed by the above experiments, the Navy Department became actively interested in the development of wireless telephone apparatus for use on battleships. Experimental sets were developed by the Western Electric Co. and extremely promising results were secured. The Signal Corps was likewise interested in the development of apparatus for the Army, but experiments had not proceeded to the point where any satisfactory apparatus had been developed prior to the declaration of war by this country.

FIELD OF MILITARY APPLICATION.

Prior to the beginning of the European War the use of wireless telegraphy in military operations had been limited to an extremely narrow field, while wireless telephony had been used to an entirely negligible extent. The communication requirements for the armies engaged in the trench-warfare style of conflict emphasized the need of radio communication, and accordingly the extent and variety of the apparatus for wireless telegraphy increased rapidly. At the time this country entered the war wireless telegraphy comprised an extremely important and extensive part of the communication systems employed on the western front. The development of wireless telephony, however, had not proceeded to the point where satisfactory apparatus was available for use by the military forces. The particular field which most urgently required its use was the airplane communication system. The limitations imposed on the use of wireless telephony, such as greater weight and complication of the apparatus and complete lack of secrecy, had hitherto prevented favorable consideration of wireless telephony as a substitute for wireless telegraphy. The particular requirements of the airplane communication, however, introduced certain advantages which more than compensated for these factors and made telephony much more desirable than telegraphy. The controlling reason for the use of the wireless telephone lay in the fact that its use eliminated the necessity of a knowledge of the telegraph code on the part of the aviator. An additional advantage lay in the greater speed with which the telephone transmission can be effected.

Inasmuch as the airplane wireless telephone set comprises not only the most interesting example of the use of wireless communication

during the war, but furnishes also a remarkable example of the rapidity with which the engineering and manufacturing facilities of this country were adapted to war-time needs, a detailed summary of the development, production, and operation of this set forms an important part of the general subject of wireless telephony.

HISTORICAL REVIEW.

Almost immediately following the declaration of war by this country the Chief Signal Officer of the Army issued orders for the development of an airplane wireless telephone set which was to furnish telephone communication between the different airplanes of a squadron and also to furnish communication between an airplane and a ground station. The fundamental requirements for this set were based partly on information furnished by the Allies and partly on the experience of the United States Signal Corps in the prewar experiments in airplane radio telegraphy and telephony. The actual development work was intrusted to the engineering department of the Western Electric Co., with provision for the necessary airplane facilities and information to be supplied by the Signal Corps as required. The progress of the development work was extremely rapid, successful communication being established between an airplane and a ground station within six weeks from the date the development was started. The evolution of a complete design suited to commercial production likewise proceeded very rapidly, so that by December, 1917, only six months from the time the development work was started, the design of the complete equipment had reached the stage where production of the sets in quantity could be authorized. As early as October, 1917, the apparatus had been developed to a sufficiently complete extent to warrant sending samples to the expeditionary forces for test under conditions existing at the front.

Because of the extreme need for the earliest possible delivery of apparatus in large quantities to meet the needs of the airplane program of the United States the production of airplane telephone sets was begun prior to the completion of the experimental work. As further experiments indicated the need of modification or refinements in the design the necessary changes were incorporated in the process of manufacture, so that the sets delivered in the spring of 1918 embodied the results of experimental work extending almost up to the date of completion of the sets.

Beginning early in the summer of 1918 the development of an improved type of set was begun, and at the time of the armistice this development had reached the point where practical trials of the completed sets were in progress. The essential differences be-

tween the original type of set and this new set are described in some detail in succeeding paragraphs.

The production of several thousand of the airplane wireless telephone sets in the brief space of a few months involved many problems of an extremely unusual and difficult nature. As an example may be cited the production of the vacuum tubes required for use in the sets. Prior to the war the vacuum tubes had never been produced at rates greater than a few hundred tubes per week. At the time of the armistice the production of these tubes in one factory alone was in excess of 25,000 per week, the largest part of which was intended for use with the airplane wireless telephone sets. The problem of devising methods for testing the completed sets involved the development of unusual testing facilities and the creation of a large organization of inspectors to handle the sets as rapidly as they were delivered from the factory. It was obviously impossible to test each completed set in an airplane before considering it as finally accepted, so that the formulation of the testing specifications involved the development of tests which would approximate the conditions encountered on airplanes and at the same time would be adapted to factory methods of testing.

Before the development of the airplane wireless telephone sets had proceeded even to the point where success was assured, it became apparent to those involved in the work that the production of a satisfactory set was by no means the complete solution of the problem. The successful use of the equipment would undoubtedly require a considerable amount of training of the aviators and a very considerable period of experiment with the trained aviators using the equipment before its limitations and its possibilities could be even approximately determined. Accordingly preparations were made in advance of the delivery of the first production sets, to institute a course of training which was intended both to familiarize the aviator with the actual use of the set and to work out the method of use; in other words, the tactics of a voice-commanded airplane squadron. As early as May, 1918, groups of airplanes using the wireless telephone sets were being trained in the use of this equipment and were being drilled in the evolutions which the equipment made possible. In June, 1918, a squadron of 39 airplanes, equipped with wireless telephone sets, went through a course of drill in the air in such a manner as to demonstrate the remarkable possibilities of a voice-commanded squadron. Subsequently the training of aviators in the tactics of "V. C." flying progressed at a rapidly increasing rate, so that at the time of the signing of the armistice many thousand flights had been made. The record of these flights is a glowing tribute to the efficiency of the design of the airplane wireless telephone sets, which performed in such a manner as to give far less trouble than the airplane engine.

AIRPLANE SETS.

At the outset of the war-time development work on the airplane wireless telephone apparatus the requirements which the apparatus would have to meet and the particular conditions under which it would operate were largely unknown; this information became apparent more or less gradually during the progress of the development work, which fortunately proceeded along such lines as to substantially comply with the requirements as they developed. As originally conceived, these requirements may be briefly stated as follows:

The apparatus should be capable of effecting reliable telephone communication between two airplanes at distances up to 2,000 yards.

The weight of the apparatus should be the minimum possible consistent with meeting the range requirements and other conditions imposed on the operation.

The apparatus should be of the simplest possible construction and should require the minimum amount of adjustment or manipulation by the aviator.

It was realized that special conditions would be encountered on the airplane which would make the development work extremely difficult and would require radical departures from any previous practice. Among these special conditions may be mentioned the tremendous noise and vibration created by the engine and wind, the necessity of reducing the fire hazard to a minimum, and, above all, the extremely essential condition that the wireless telephone apparatus must create the minimum possible interference with the various other functions of the aviator.

The various elements comprising the complete wireless telephone set may be grouped into the following units: Power plant, transmitting unit, receiving unit, antenna system.

The details of these various units and the problems encountered in their development are briefly described in the following paragraphs:

POWER PLANT.

The preliminary experiments with various types of apparatus soon determined the power requirements of the apparatus which included power supply for the filament and plate circuits of the vacuum tubes for both transmitting and receiving circuits and power for the telephone transmitters. The filament power required was determined to be 1.35 amperes at 24 volts and the plate circuit power for the transmitting set 0.070 amperes at 275 volts. The plate current for the receiving tubes was extremely small, namely, less than 0.004 amperes, and it was decided to furnish this power from dry batteries.

After various arrangements were tried the current for the telephone transmitter was obtained by shunting this transmitter about filaments of two vacuum tubes which gave approximately the correct voltage for operating this transmitter. The 24-volt and 275-volt power is obtained from a double voltage direct current generator which is driven by an air fan, the complete generator being mounted on one of the struts of the landing gear of the airplane and hence being directly in the propeller blast. The most difficult problems involved in the design of the generator were those related to the excessive speed variation and the extremely high maximum speed at which the generator was required to operate. The air speed of the plane being subject to extremely wide variations and the air fan rotational

speed varying in almost exactly the same ratio, it was necessary for the generator to furnish its normal voltages over a speed range of 4,000 to 12,000 revolutions per minute. This required the use of a special voltage regulator, the circuits of which are shown in figure 1. This regulator depends for its operation upon

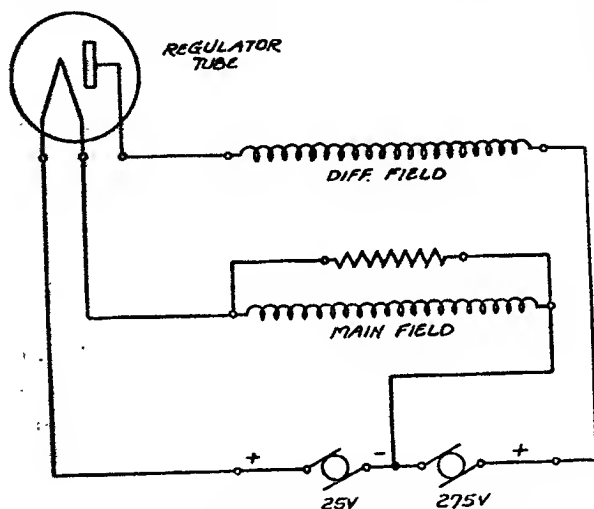
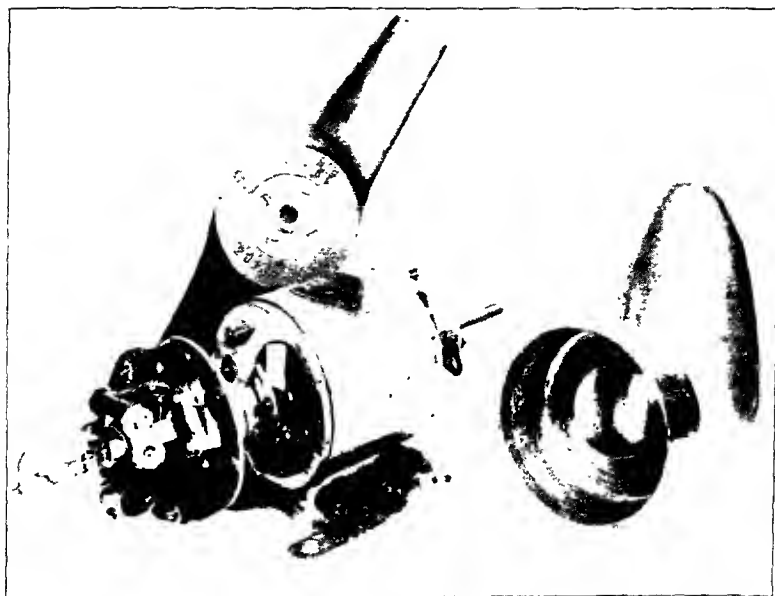


FIG. 1.—Circuit diagram, wind-driven generator.

the relation existing between the filament current and the electron emission from the filament in a special vacuum tube which has been designated as a regulator tube. At the lower limit of the operating speed range, namely, 4,000 revolutions per minute, the filament of this regulator tube operates at a temperature which gives practically no emission of electrons. As the speed of the generator increases above this value the voltage rises, and accordingly the temperature of the regulator tube filament increases. This results in an extremely rapid increase in the number of electrons emitted by the regulator tube filament, which in turn causes a rapid increase in the current flowing through the differential field and the plate circuit of the regulator tube, as shown by the characteristic curves of figure 2. This current tends to reduce the total magnetization of the generator, and as a result, the voltage regulation is maintained within extremely close limits.



WIND-DRIVEN GENERATOR, FAN, AND REGULATOR TUBE.

While this voltage regulating device operates in an extremely satisfactory manner, the excessive speed variation of the generator imposes certain other requirements on the generator design which make it desirable to reduce this speed variation. The development of a constant-speed air fan has progressed practically to the point where designs are available for an air fan which will give an almost exactly constant rotational speed with a range of air speeds of at least 4 to 1. The use of such an air fan on future wind-driven generators for airplanes is a practical certainty.

Various alternatives, such as storage batteries and a dynamotor, or a double voltage generator driven directly from the airplane engine, were considered and rejected in favor of the generator above described.

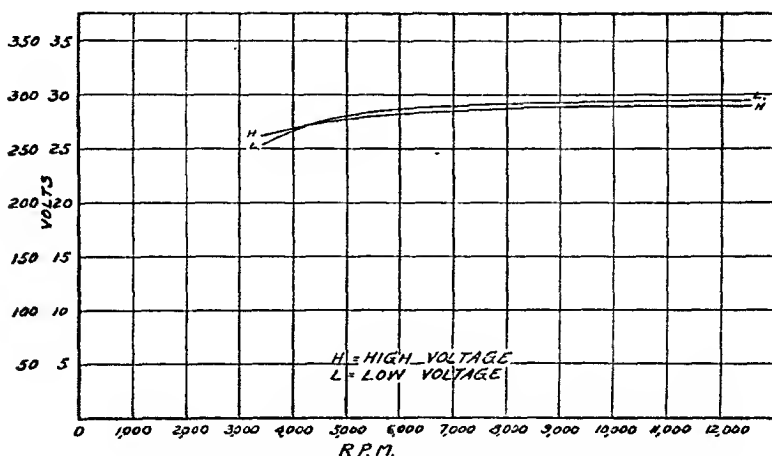


FIG. 1a.—Voltage characteristic, wind-driven generator.

TRANSMITTING SET.

The circuits of the transmitting set are shown schematically in figure 3. A single vacuum tube of a special type is used for furnishing the radio frequency current and a similar tube is used for modulating the radio frequency current. The method of modulation employed is known as the "constant current" method and may be described briefly as follows:

The plate circuits of the vacuum tube oscillator and modulator are connected in parallel and are supplied through an inductance coil, which tends to maintain the total current constant. The plate current taken by the modulator tube is controlled by its grid voltage, which in turn is determined by the operation of the telephone transmitter. These voice frequency fluctuations of the modulator plate current cause corresponding variations in the direct current supplied to the plate circuit of the oscillator tube, the sum of the two currents

at any particular instant being substantially constant. These variations in the direct current supply of the oscillator tube result in corresponding variations of its high frequency output so that the result is a modulated radio frequency current supplied to the antenna.

The telephone transmitter furnished one of the most difficult problems in connection with the design of the transmitting set by reason of the fact that this transmitter operates under conditions of such extreme noise, due to the wind and engine exhaust. After a very extended period of development the present form of transmitter

was perfected, its improvement over the ordinary form being roughly indicated by the statement that the ratio of noise signals to speech signals in the output of this transmitter is probably less than 1 per cent of the same ratio for a transmitter of the usual type.

Reference to the schematic diagram indicates the adjustments of the transmitting set for different wave lengths to include only a variable inductance and a variable capacity. Inasmuch as the apparatus is adjusted for a particular wave length before the airplane leaves the ground, an artificial antenna whose constants approximate those of the normal antenna is

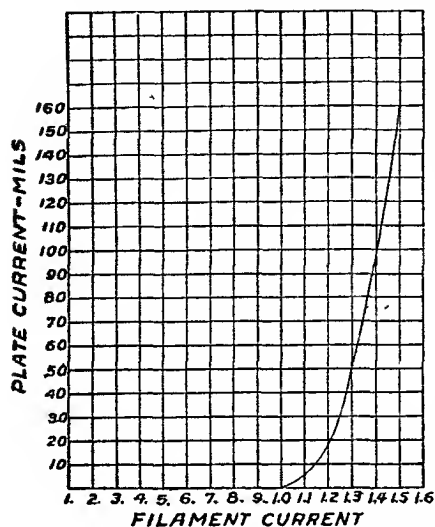


FIG. 2.—Characteristic curve, regulator tube.

used for making such adjustments on the ground.

RECEIVING SET.

The circuits of the receiving set are likewise shown schematically in figure 3. Reference to this figure will indicate that the circuit comprises a single resonant circuit, a vacuum tube detector, two vacuum tubes used as amplifiers, and a special helmet containing the receivers. The detector and amplifier are not particularly novel in any respect, but the helmet containing the receivers is of very unusual construction. The same noise conditions which were mentioned above for the telephone transmitter likewise affected the reception of signals in the telephone receivers. It was accordingly necessary to develop a special sound-insulating helmet in which the telephone receivers were mounted in such a way as to exclude almost completely from the aviator's ears all sounds except those emanating

from the telephone receivers. The design of a helmet which would accomplish this and at the same time not prove to be uncomfortable represents one of the most striking accomplishments in the complete set.

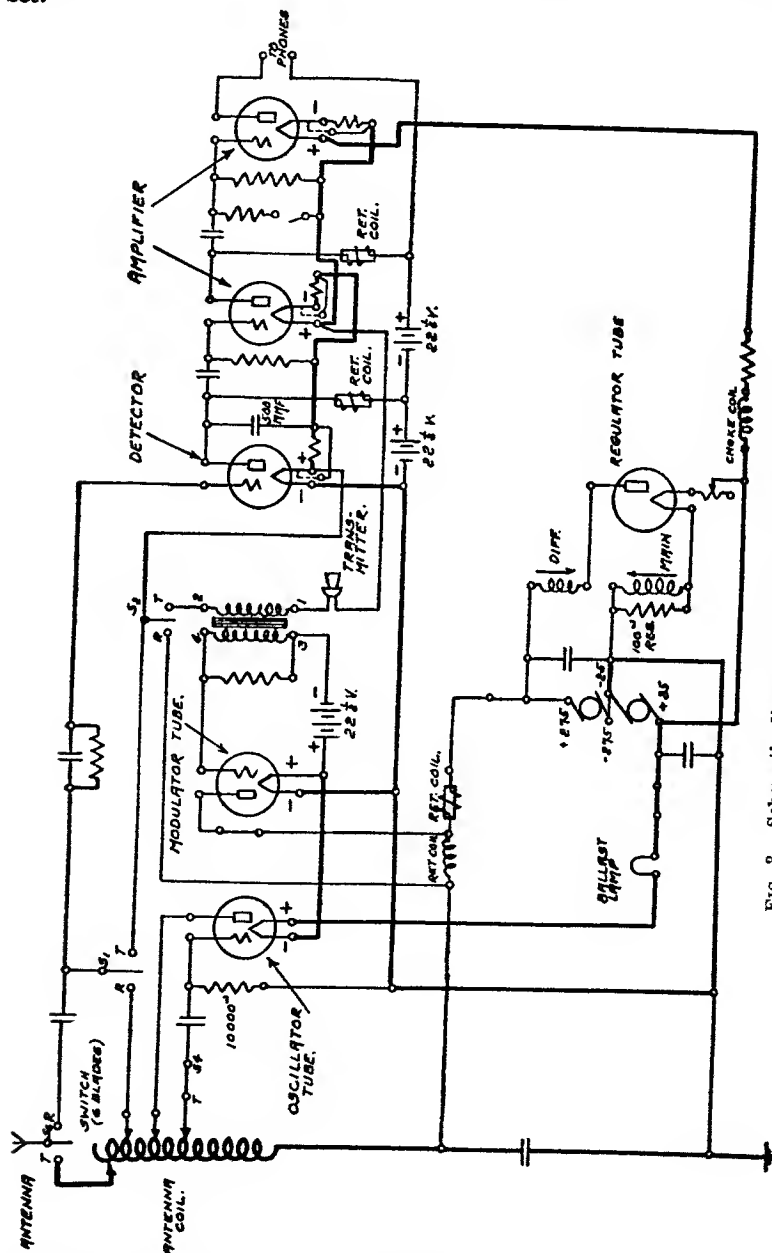


FIG. 3.—Schematic diagram, airplane wireless telephone.

The adjustment of the receiving set is of the utmost simplicity, there being only a variable capacity and inductance to adjust for the

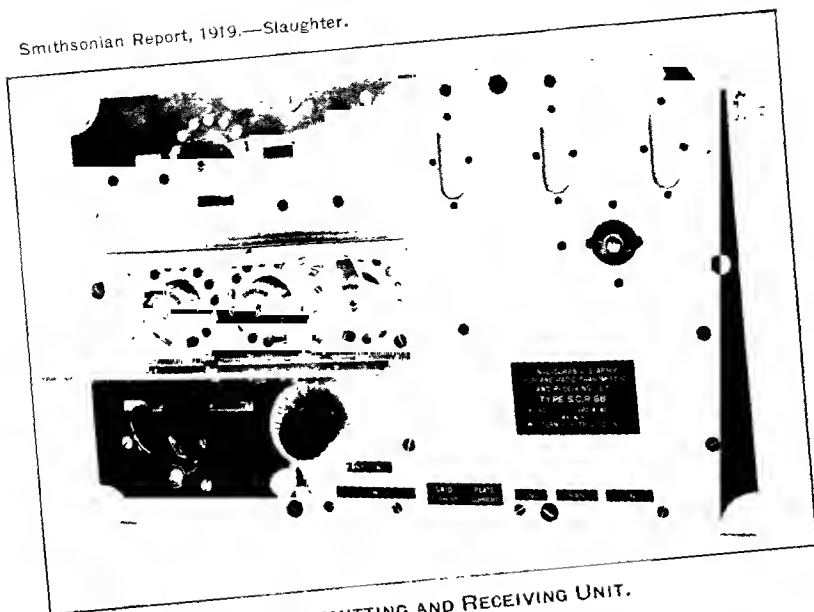
particular wave length of the received signal. As in the case of the transmitting set, these adjustments are ordinarily made before the plane leaves the ground, and it is usually necessary for the aviator to make in flight only an extremely small adjustment in the capacity to insure the proper tuning of the receiving set. Because of the condition of vibration existing on the airplane and the effect of this vibration on the vacuum tubes used in the receiving apparatus, it was necessary to devise a mechanical filter which would protect the vacuum tubes from these vibrations. The method finally adopted consisted of the use of sponge rubber supports for certain elements within the set box itself.

The current required by the plate circuits of the receiving tubes and the negative grid potential for the modulator tube of the transmitting set are furnished by small dry batteries, which consist of 15 cells of very special construction weighing less than 1 pound and having sufficient current capacity to operate the set a few hours a day for a considerable number of weeks. The most important requirement for these batteries, however, was a sufficient length of shelf life, inasmuch as a period of several months usually elapsed between the date of manufacture and the date of use. Difficulties of securing even a few months' shelf life for cells of such small size made the use of standard cells out of the question. Development of particular types of containers for the cells and extremely careful selection of materials resulted in the satisfactory solution of this problem.

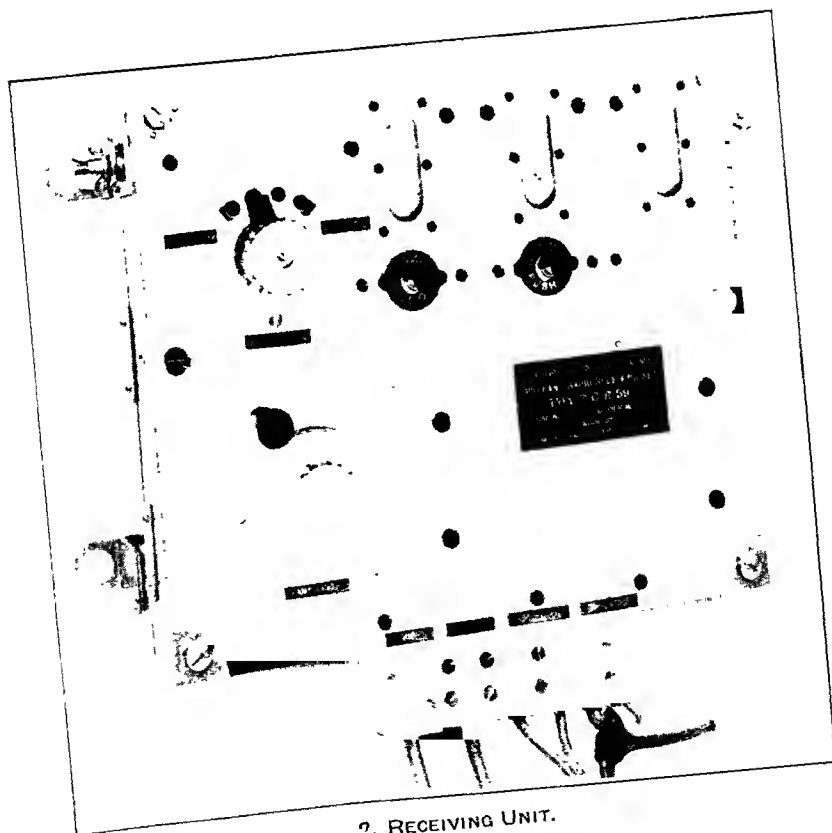
ANTENNA.

The form of antenna which was adopted for the early experiments with the airplane wireless telephone consisted of a wire trailing behind the airplane in flight and connected through the apparatus with the frame of the airplane as a counterpoise. The length of this wire was ordinarily 300 feet. A reel was provided for holding this wire and a small weight was attached to the free end to cause it to unreel properly after the airplane left the ground. In order to reduce the attention required by the aviator in unreeling the antenna a special form of reel was devised with a centrifugal governor, which limited the unreeling speed to a value which prevented the weight from breaking the wire at the end of the unreeling process. The wire which was used was a soft braided copper wire made purposely of low tensile strength, so that in case this wire became entangled with any obstruction during flight no particular strain would be put upon the airplane structure before the antenna wire would break.

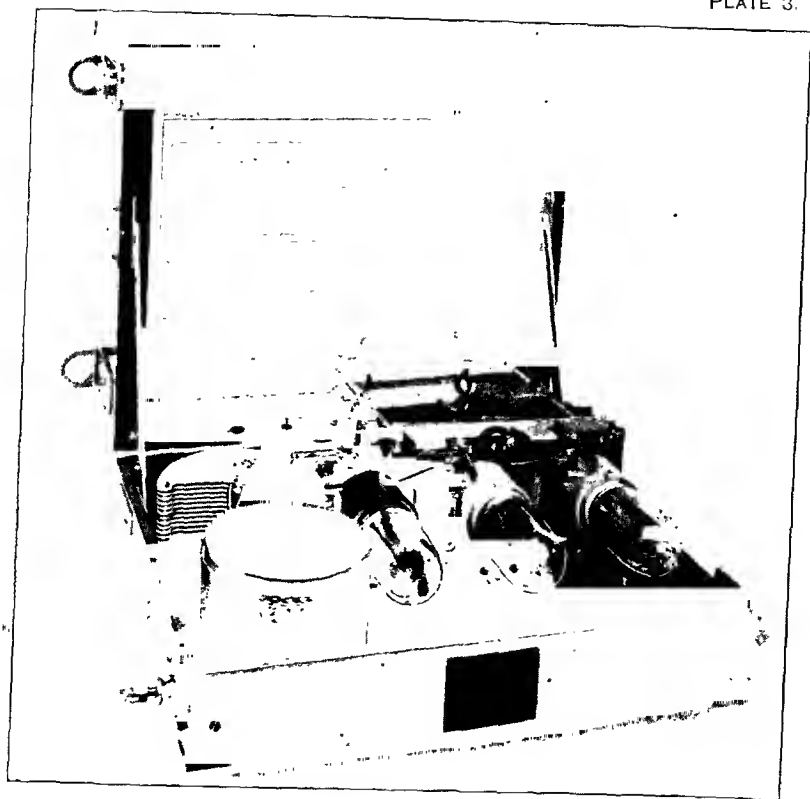
The subject of radiation from airplane antennae has perhaps received less attention in proportion to its importance than almost



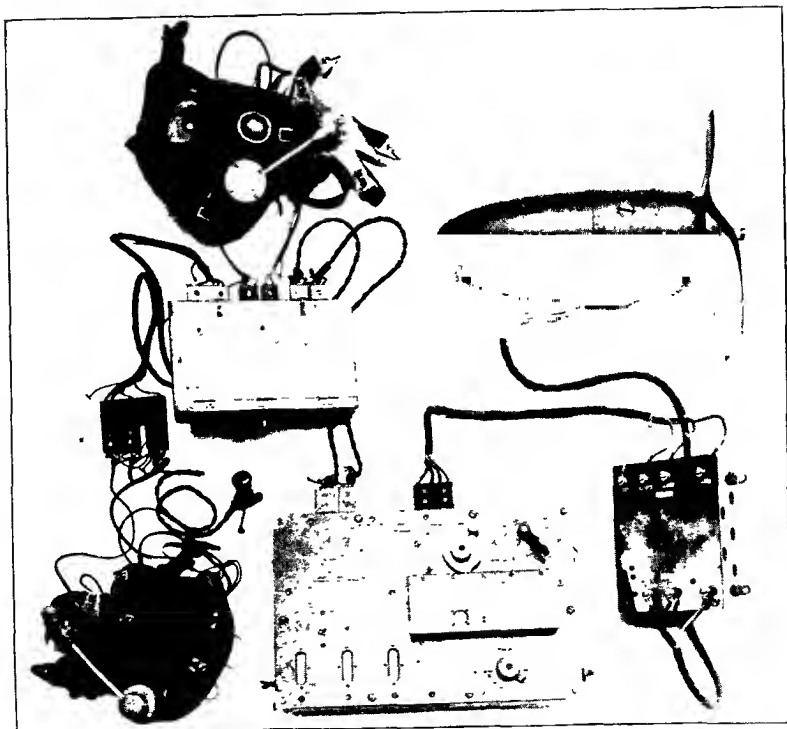
I. TRANSMITTING AND RECEIVING UNIT.



2. RECEIVING UNIT.



RECEIVING UNIT (OPEN).



COMPLETE TRANSMITTING AND RECEIVING SET.

any other phase of airplane wireless telephony. This is partly due to the fact that the form of antenna above described possesses extremely efficient radiating properties and partly to the fact that investigations of the subject require very extensive and painstaking measurements involving actual flights of airplanes. The investigations conducted during the war, however, included a large number of tests of various types of antenna, the principal object of which was to evolve a substitute for the long trailing wire which would be better adapted for use on airplanes engaged in acrobatic flying. Obviously the movements of an airplane were somewhat restricted by the use of this type of antenna.

Without indicating in detail any of the alternative types of antenna which were developed and used it may be stated there are a number of forms of airplane antenna which offer considerable promise of complying with the radiation requirement and at the same time offer practically no interference with the movements of the airplane.

The tactical uses of the airplane wireless telephone called for transmission and reception on certain airplanes and for reception only on other airplanes. The apparatus developed therefor included two distinct types, one including both the transmitting and receiving elements mounted in a single box, as shown in plate 2, figure 1, while the other included only the receiving element, as shown in plate 2, figure 2, and plate 3. The complete equipment comprising the transmitting and receiving set is shown in plate 4. The complete equipment comprising the receiving set only is different with respect to the power plant, which in this case consists of a 4-volt storage battery. This figure shows two telephone transmitters and two helmets, which are used in connection with an interphone system provided as an auxiliary to the wireless telephone. This interphone system enables two persons in the same airplane to converse with each other by ordinary telephone, and furnishes in itself a valuable communication system entirely exterior to the wireless telephone apparatus.

Where communication between an airplane and a ground station is desired this communication is effected by means of a special ground set which has been developed to correspond with the range and wavelength requirements of the airplane apparatus.

In using the apparatus above described, the only manipulation required of the aviator is switching from the transmitting to the receiving apparatus, or vice versa, as required. Ranges of several miles between planes are easily accomplished, and under extremely favorable conditions much greater distances have been covered.

NEW TYPE OF APPARATUS.

Experience in the operation of the above type of wireless telephone apparatus indicated the desirability of certain improvements, particularly along the following lines:

Reduction in the size of the apparatus units to better adapt them to installation in the restricted space available on certain types of airplanes.

Use of very much shorter wave lengths to make possible the substitution of antennæ which would not interfere with the use of the airplane and which would likewise reduce the amount of radio interference which would be experienced on the western front.

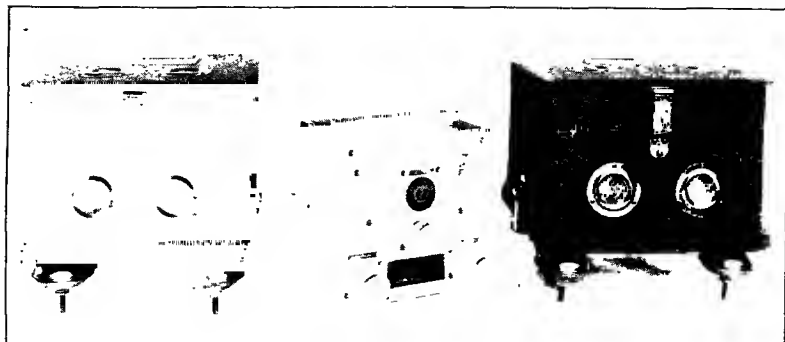
Accordingly, a new type of set was developed during the summer of 1918, the essential elements of which are illustrated in plates 5 and 6. Practical trials of this equipment have not proceeded sufficiently to indicate the superiority of this set from the standpoint of its use by the aviator. Its superiority, however, from the standpoint of installation is self-evident.

WIRELESS VERSUS WIRE TELEPHONY.

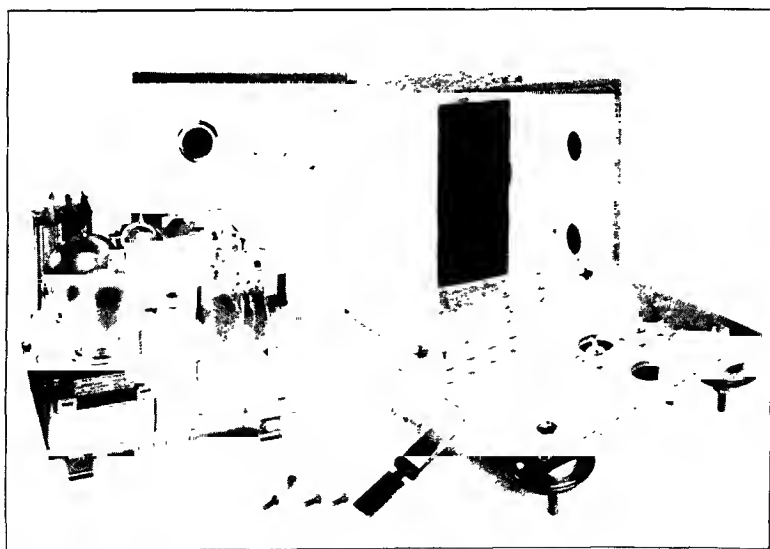
Any prophecy as to the future of the wireless telephone art should take due account of fundamental differences between wire and wireless telephony. While it is conceivable, though not probable, that improvements in directive radiation may be evolved which will cause the greater part of the waves radiated from a wireless station to choose a particular path, rather than to be spread broadcast, as at present, there will always be a far more definite and restricted path for wire telephone signals than for wireless signals. As a result, it may be safely predicted that wireless telephony is not apt to supersede wire telephony in any of the fields now occupied by the latter. The application of wireless telephony to new fields, where wire telephony is either impossible or impractical from economic considerations, will furnish abundant opportunity for service of the greatest value. A combination of wire and wireless telephony, each in its own field, may result ultimately in a telephone system covering the civilized world.

COMMERCIAL FIELD.

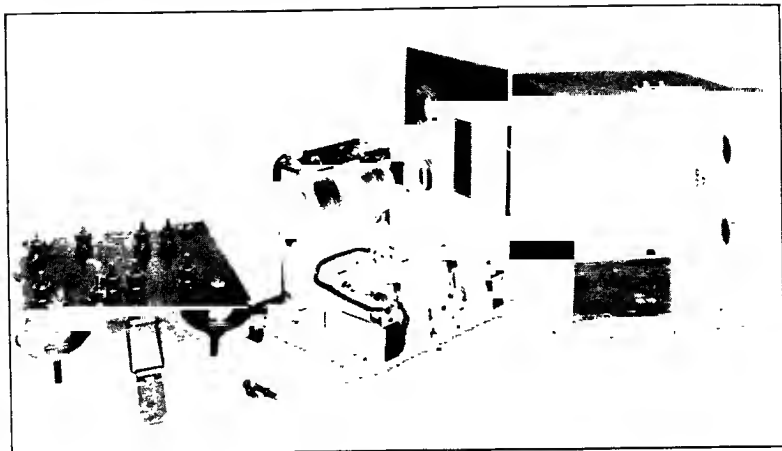
To the average person the most interesting commercial application of wireless telephony is transoceanic, such as is suggested by the long-distance experiments mentioned above. While the scientific aspects of the question are such that the development of suitable apparatus for effecting reliable commercial service between such points as New



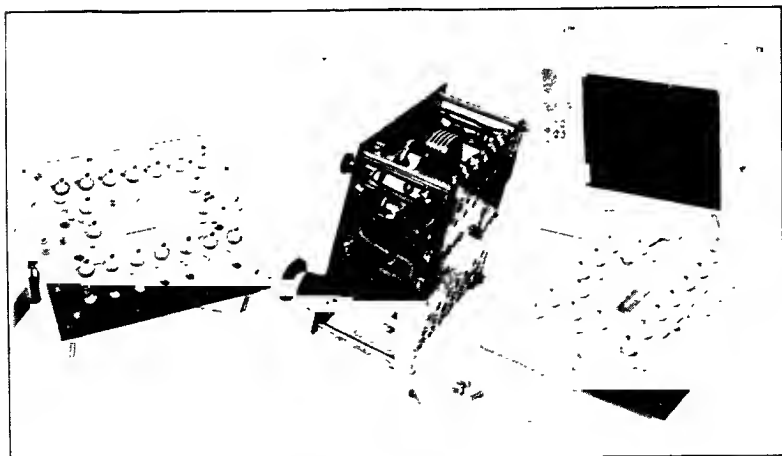
NEW TYPE OF AIRPLANE WIRELESS TELEPHONE.



TRANSMITTING UNIT ALONE.



RECEIVING UNIT ALONE.



CONTROL UNIT ALONE.

York and London is a comparatively simple matter, economic questions have up to the present prevented serious consideration of such a project. It is entirely conceivable that improvements in the art may soon bring the cost of such a system well within the limits imposed by economic considerations.

Wireless telephony between ships at sea or between a ship and a shore station is a logical supplement to the wireless telegraph service now furnished on practically all ocean-going steamships. In this case, as in the case of transoceanic telephony, economic considerations are apt to retard the extension of this field until the development of apparatus less expensive than present types.

In the field of aviation, however, wireless telephony presents a number of advantages which it is believed will result in its rapid adaptation to the needs of this service. Entirely aside from the popular interest attached to telephone communication between different airplanes, or between an airplane and a ground station, the practical value, particularly of the latter, is sufficient in many cases to justify the required expenditure to provide this facility.

There are various special fields not included in the above which may call for the use of wireless telephony, such as communication between various islands of a group—for example, the Hawaiian Islands—the wireless telephone furnishing in this case trunk lines for tying together the telephone exchanges on the various islands.

MILITARY FIELD.

The use of wireless telephone apparatus in combatant military operations during the war was practically negligible. This should, however, not be interpreted as an indication that wireless telephony offers no advantages for military purposes, but rather that the training of personnel in its use had not proceeded sufficiently to warrant its use. Communications within various units of an army frequently call for extreme mobility of the apparatus. The prevailing method of establishing intermittent communication between temporary stations joined by wires laid on the ground is obviously far from ideal. If wireless telephone apparatus can be developed by means of which different centers of command can be kept in constant touch with each other while all are in motion the advantages of such communication will compel its adoption and wide use throughout the communication system of the Army.

In naval operations the use of wireless telegraphy is so widespread that it forms an indispensable link in the naval communications system. For certain kinds of service the advantages offered by telephony as compared with telegraphy make it extremely desirable that wireless telephone apparatus be developed to meet the require-

ments. The present state of the art indicates the certainty that this can be done.

In the field of military aviation wireless telephony finds its greatest present opportunity for immediate service. The requirements of interairplane communication are such that the telephone is peculiarly adapted. The use of wireless telephony within an airplane squadron at once makes possible the development of the squadron into a military unit wherein the various members are subject to the command of the leader in exactly the same way as military units on land and water. The development of airplane squadron tactics is therefore made entirely possible, whereas without the telephone it is considered that the difficulties of communication between various airplanes would have made such a development impossible. Communication between airplanes and ground stations comprises an equally important phase of the operation of military aircraft. Hitherto these communications have been chiefly those for directing artillery fire and the wireless telegraph has served this purpose reasonably well. The availability of the wireless telephone, however, will open up new possibilities in the use of airplane to ground communication, an example of which is furnished by the present operations on the Mexican border. Scouting parties, accompanied by airplanes, traverse the extremely mountainous country, with airplanes preceding the land forces and at intervals reporting their observations. If we imagine each of the scouting parties to be equipped with receiving apparatus sufficiently portable so that it does not in any way interfere with the movements of the party, it is at once evident that they could, without delay, be kept informed of the observations of the aviator, by direct telephone communication. This extension of range of vision would be of immeasurable value.

Developments which have occurred during the war period, while essentially of a military character, are immediately applicable to both military and commercial needs. These developments point the way to further progress in the art which it is believed will, within a short time, establish wireless telephony as an important element in many phases of our military and commercial activities.

RADIUM AND THE ELECTRON.¹

By SIR ERNEST RUTHERFORD, F.R.S.

When we view in perspective the extraordinarily rapid progress of physics during the last 25 years, we can not fail to be impressed with the great significance to be attached to the discovery of X-rays by Röntgen in 1895, not only from its intrinsic interest and importance, but also from the marked stimulus it gave to investigations in several directions. In fact, this discovery marks the beginning of a new and fruitful epoch in physical science, in which discoveries of fundamental importance have followed one another in almost unbroken sequence.

It does not fall within my province to discuss the great advances in our knowledge that have followed the close study of this penetrating type of radiation, but to indicate, I am afraid very inadequately, the progress in two other directions of advance which were opened up by the discovery of X-rays, and have revolutionized our ideas of the nature of electricity and the constitution of matter.

Following Röntgen's discovery, attention was concentrated on two aspects of the problem. On the one side it was thought that the excitation of the X-rays might be connected with the phosphorescence set up in the glass of the discharge tube by the impact of cathode rays, and experiments were consequently made by several observers to test whether substances which phosphoresced under ordinary light emitted a type of penetrating X-rays. By a fortunate combination of circumstances, H. Becquerel in 1896 tried the effect of a phosphorescent uranium salt, and this led to the discovery of the emission of a penetrating type of radiation, and thus laid the foundation of the new science of radioactivity, the further development of which has been attended by such momentous consequences.

On the other side, the problem of the nature and origin of the X-rays led to a much closer study of the cathode rays and to the definite proof, as Sir William Crookes had long before surmised, that the cathode rays consisted of swift charged particles of mass small compared with that of the hydrogen atom. It was soon shown that these corpuscles of small mass or negative electrons, as they are now termed, could be set free by a variety of agencies, by the action

¹ Reprinted by permission from *Nature*, Nov. 6, 1919.

of ultra-violet light on metals and copiously from glowing bodies, while they were ejected with high speed spontaneously from the radioactive bodies.

The interpretation by Lorentz of the Zeeman effect in which the spectrum lines were displaced by placing the source of light in a magnetic field showed that electrons of the same small mass were present in all atoms, and that their vibrations constituted visible light. Sir J. J. Thomson early pointed out the significance of the electron as one of the units of atomic structure and its importance in the mechanism of ionization in gases, and the rapid growth and acceptance of electronic ideas owes much to his work and teaching. An important stage in advance was the proof by Kaufmann that the mass of the electron was entirely electrical in origin. Sir J. J. Thomson had shown in 1881 that a charged particle acquired additional or electrical mass in virtue of its motion. The variation of mass with speed has been shown to be in accord with general theory, but is in best agreement with the formula based on the theory of relativity. It would be of great interest to compare theory with experiment for the highest attainable speed of the electron from radium which is so near to the velocity of light that the variation of mass with velocity is very rapid.

The proof that the electron was a disembodied atom of negative electricity was a great step in advance in electrical ideas. Information as to the nature of positive electricity is far less precise and definite, for no positive electron, the counterpart in mass of the negative electron, has ever been observed. In all experiments with positive rays and with radioactive transformations where the processes are very fundamental in character, no positive charge has ever been found associated with a mass less than that of the atom of hydrogen. While it is well to keep an open mind on this fundamental question, the evidence as a whole suggests that there is an essential difference in mass between the carriers of positive and negative electricity. In fact, such a difference seems to be essential to fit in with our knowledge of the structure of atoms. The nucleus of the lightest atom, hydrogen, may prove to be the positive electron and its much greater mass than that of the negative electron would then be ascribed to the greater concentration of the electrical charge in the former.

From consideration of the passage of electricity through gases, it had long been surmised that electricity, like matter, was atomic in character. The study of the deflection of the cathode rays and α -rays in magnetic and electric fields showed that the carriers of each type had all the same charge, and the atomic nature of electricity was implicitly assumed by all workers. Townsend showed

that the charge carried by the ions in gases was equal to the charge carried by the hydrogen atom in the electrolysis of water and made the first measurements of this fundamental unit. Other methods of attack were developed by Sir J. J. Thomson and H. A. Wilson, and by a skillful adaptation of methods Millikan was able to demonstrate in a very direct way the unitary nature of electricity and to measure the value of the unit charge, probably the most important and fundamental constant in physics, with an accuracy, it is believed, of one in a thousand. By combining the value of this constant with electro-chemical data, the number of molecules in a cubic centimeter of gas and the mass of the atoms can be deduced with equal accuracy. The convincing proof of the atomic nature of electricity and the accurate measure of the fundamental atomic and molecular magnitudes are two of the greatest triumphs of the new era.

One of the most important properties of X-rays is their power of making gases a temporary conductor of electricity. The study of this small conductivity led to a clear idea of the transfer of electricity through gases by means of charged ions, and the nature and difference of the positive and negative ions have been closely studied. The proof by Townsend of the production of ions by collision in electric fields opened up a new field of investigation and gave us for the first time a clear idea of the processes leading up to an electric spark. The ionization theory was found to explain the conductivity produced by radium rays and the conductivity of flames. The laws controlling the escape of electricity from glowing bodies were closely examined by H. A. Wilson and O. W. Richardson.

It is a striking fact that these purely scientific researches on the conductivity of gases, which had their inception in the Cavendish laboratory, and appeared at first to have only an academic interest, should so soon have resulted in important practical applications. We may instance the use of a hot filament in a low vacuum as a rectifier of alternating currents and a detector of electrical waves. The supply of electrons from a glowing filament coupled with the generation of ions by collision has led to the production of powerful electric oscillators and amplifiers for magnifying minute currents to any desired degree. These amplifiers have not only been of great service in war, but have also rendered possible radiotelephony across the Atlantic. Last, but not least, we have the invention of the Coolidge X-ray tube, which has played such an important part in research and radiography.

While the mechanism of ionization of gases by X-rays and radium rays and the transfer of electricity in ordinary electric fields is in the main well understood, it is a striking fact that the passage of the disruptive discharge through a vacuum tube, which was the

starting point of so many discoveries, is still almost a mystery. While, no doubt, some of the main factors involved in the discharge are known, the phenomena in gases at low pressure are so complex that we are still far from a complete elucidation of the problem. This complexity is well instanced, for example, by the sign and magnitude of the charges communicated to atoms and molecules in the positive rays, which have been so closely studied by Wien and Sir J. J. Thomson, and in the hands of the latter have given us a very delicate method of chemical analysis of gases in a discharge tube.

The discovery of the electron as a mobile constituent of the atom of matter has exercised a wide influence on electrical theory, and has been the starting point of attack on numerous electrical problems. In these theories the electron may be considered as a point charge with an appropriate mass associated with it, and in many cases no assumptions as to the nature and constitution of the electron itself are involved. One of the first problems to be attacked was the passage of electricity through metals where it was supposed that the negative electrons are continuously liberated from the atoms, and are in temperature equilibrium with the matter. While the theories as initially developed by Drude and Sir J. J. Thomson have been instrumental in accounting for a number of relationships, they are unsatisfactory on the quantitative side. These difficulties have been enhanced by the recent discoveries of Kamerlingh Onnes of the supraconductivity of certain pure metals at very low temperatures and the marked departure from the law of Ohm under certain conditions. As in the case of the theory of radiation, it may be necessary for an ultimate explanation to introduce the ideas of quanta as recently proposed by Keesom. Langevin has applied the electron theory to the explanation of magnetism and diamagnetism, but there are still many difficulties. The suggestion, first proposed by Weiss, that there exists a natural unit of magnetism called the magneton, analogous in some respects to the atom of electricity, still lacks definite confirmation.

In this brief review reference can be made only to the apparently insoluble difficulties in the explanation of the facts of radiation brought to light in recent years, and to the application of the theory of quanta which has had such a large measure of success in many directions.

RADIOACTIVITY.

The rapid growth of the subject of radioactivity after the discovery by Becquerel of the radiating power of uranium was greatly influenced by the discovery and isolation of radium in 1899 by Mme. Curie, for the radioactive properties of this element were on such a

scale of magnitude that they were difficult to explain and still more difficult to explain away. The systematic chemical analysis of uranium ores disclosed the presence of new radioactive substances like polonium and actinium, while the study of thorium, radium, and actinium disclosed the emission of radioactive emanations or gases and their apparently remarkable power of conferring temporary activity on all bodies in their neighborhood. The changes in activity of these substances with time and the different types of radiation emitted at first gave an appearance of great complexity and confusion to the rapidly accumulating mass of facts, but the whole subject took on an orderly and systematic development after the transformation theory was put forward by Rutherford and Soddy in 1903 as an explanation of radioactivity. On this view radioactive matter is undergoing spontaneous transformation of its atoms with the appearance of a succession of new radioactive bodies, each marked by characteristic chemical and radioactive properties. The radiations accompany the transformation of atoms and are a measure of the rate of transformation. Guided by this theory, the whole sequence of changes in the uranium-radium series, the thorium and actinium series, were investigated in detail, and in a remarkably brief space of time more than 30 new radioactive elements were brought to light and their position in the scheme of radioactive changes determined. Special interest attaches to the discovery by Boltwood of the substance called ionium, which is directly transformed into radium. This afforded a direct experimental method of determining the average life of radium with a result that is in close accord with the value calculated from the rate of emission of α -particles. The position of actinium in the main scheme of changes has occupied much attention. The constancy of the relative amount of actinium and uranium in uranium minerals showed that it must be derived ultimately from uranium, but the activity of actinium is too small to be in the direct line of succession. This has led to the view that actinium is a branch product at some point of the uranium series where about 6 per cent is transformed into the actinium branch and 94 per cent into the main line of descent. The general evidence indicates that this branching occurs near to uranium, and possibly the branch product called uranium-Y by Antonoff is the first member of the family. Recently the intermediate parent substance of actinium itself has been discovered.

While in the majority of cases the atoms of a radioactive product break up in a very definite fashion and in only one way, certain cases are known where one substance breaks into two chemically distinct substances. Examples of this are radium C, thorium C, and actinium C. Usually the transformation is mainly in one direction with a

small fraction in the side branch. It is quite probable that further study may lead to the discovery of a number of such dual transformations. In the violent cataclysm that must accompany the transformation of an atom, it is not unexpected that the constituents of the residual atom may arrange themselves in more than one configuration of temporary equilibrium.

Much attention has been directed to the properties of the radium emanation—the radioactive gas constantly produced by the transformation of radium atoms. The equilibrium volume of this gas from 1 gram of pure radium is only six-tenths of a cubic millimeter, but contributes more than three-fourths of the total activity of radium. By concentration of purified emanation into fine glass tubes, very powerful sources of radiation have been obtained, which have proved of great utility both in the laboratory and for therapeutic purposes. Although only about one-tenth of a cubic millimeter of purified radium emanation has ordinarily been available for experiments, methods have been devised to determine its spectrum, molecular weight, freezing and boiling points.

We owe to Hahn the discovery of two fairly long-lived products of thorium called mesothorium and radiothorium. The mesothorium, which is separated with the radium from ores containing both thorium and uranium, is transformed into radiothorium. These products can be obtained of activity greater than radium for equal weights, and give us another source of powerful radiation.

The discovery of the production of helium from radium by Ramsay and Soddy was of great importance in emphasizing the reality of the transformations occurring in radium. Rutherford showed that the α -rays which are shot out from radium consist of positively charged atoms of helium, so that all radioactive substances which emit α -rays give rise to helium. The production of helium by radioactive substances explains the occurrence of large quantities of helium in uranium and thorium minerals, and indeed the prediction by Rutherford and Soddy that helium would prove to be a product of radioactive transformation was based in part on this fact.

The great majority of radioactive substances are transformed with the expulsion of helium atoms with great velocity, but in a few cases swift electrons appear. The appearance of helium in so many changes, coupled with the observation that many of the atomic weights of many known elements differ by four units—the atomic weight of helium—indicates that helium must be one of the secondary units of which many of the ordinary elements are built up. It is noteworthy that so far no definite evidence has been obtained that hydrogen is a direct product of radioactive transformation, although its complete absence would be very surprising.

The proof by the Curies of the rapid and continuous emission of heat from radium showed clearly the vast amount of energy that must be stored up in radioactive matter and released by its transformation. This heat emission has been shown to be a secondary effect of radioactivity, for it is a measure of the energy of the expelled radiations, the greater part being due to the energy of the expelled α -particles.

The transformation of an atom is the result of an explosion of intense violence in which a part of the atom, whether a helium atom or an electron, is shot out with great speed. In order to produce α -, β -, or γ -rays of equal energy to those emitted by radioactive substances, potential differences of about 2,000,000 volts applied to a vacuum tube would be necessary. These spontaneous radiations have been of great utility in studying the ionization, scattering, and other properties of particles moving at high speed, while in the very penetrating γ -rays we have a type of X-rays of much shorter wave-length than can be produced at present or is likely to be produced by laboratory methods.

The properties of the α -rays have been very closely studied and their speed and mass have been determined accurately. The definiteness of the range of α -particles, to which Bragg first directed attention, is a matter of remark, and so far the apparent disappearance of the α -particle while still moving with a high velocity has not been adequately explained. The analysis of the β -rays has disclosed the presence of groups of electrons emitted at a definite velocity, so that the pencil of β -rays deflected in a magnetic field shows a veritable magnetic spectrum. The presence of these groups of β -rays appears to be connected with the emission of characteristic X-radiation from the atom, and the evidence as a whole strongly supports the view that the γ -rays from radioactive substances, like the X-rays from a vacuum tube, contain rays of a wide range of frequency in which the characteristic rays from the atom predominate.

Space does not allow me to do more than mention the extraordinary delicacy and definiteness of the electrical methods devised for measuring minute quantities of radioactive matter. By their aid the chemical properties of the numerous radioactive elements have been studied and their position in the periodic table established. The orderly sequence of changes in the chemical properties of successive elements in the radioactive series has been shown to be intimately connected with the type of radiation, whether α - or β -ray, emitted by the preceding element. One of the most important fruits of these chemical investigations has been the proof of the existence of nonseparable elements, named isotopes by Soddy, which are identical in ordinary physical and chemical properties, but have different atomic weights.

In the case of lead, six isotopes are already known which differ from one another either in atomic or radioactive properties. On the nucleus theory of the atom this indicates that the charges on the nuclei are the same, but that the masses differ. The proof of the presence of isotopes promises to open up a new and very fundamental field of chemical inquiry which must inevitably exercise a great influence on atomic weight determinations and also on our ideas of atomic constitution. In a recent letter to this journal Merton has indicated that the minute change in the wave length of spectrum lines of isotopes may give us a simple method of attack on this problem.

While the subject of radioactivity belongs in essence to the border line of physics and chemistry, with affiliations to both sciences, it has had numerous connections with other fields of work. The examination of the earth's crust has shown that radioactive matter is very widely distributed, and has disclosed, notably through the work of Strutt and Joly, that the heating effect due to this matter vitiates to a large extent the old arguments of the duration of the earth's heat. While showing that the old views are not tenable, radioactivity has at the same time supplied new methods of estimating the age of minerals and the duration of geological epochs. The minimum age of minerals can be deduced from the helium accumulated from the transformation of radioactive matter, and the maximum age from the accumulated lead which is the product of both uranium and thorium. Now that the atomic weights of the lead isotopes are well established, the atomic weight of the lead in a uranium mineral should serve as a definite guide to the fraction of lead present which is due to the transformation of uranium and thus give a trustworthy estimate of the age of the mineral. Joly has demonstrated in a striking way that the pleochroic halos observed in mica are of radioactive origin, and he has also estimated their age. The presence of radioactive matter in the atmosphere has been shown to account for its electrical conductivity. Just before the war evidence was obtained indicating the presence of a very penetrating type of γ radiation in the upper atmosphere. It is to be hoped that soon a further study will be made to determine the nature and origin of this interesting radiation. Finally, numerous investigations have been carried out to determine the effects of the radioactive rays on living tissue and on the growth of plants and organisms. With the increased use of radium for therapeutic purposes, it is likely that our knowledge of this important field of inquiry will grow rapidly.

It is a matter of remark that while the study of radioactivity has disclosed in a striking way the transformation of heavy atoms through a long series of stages, it has at the same time provided us with indubitable proof of the correctness of the old atomic theory of

matter. The electric method devised by Rutherford and Geiger of counting single α -particles allows us to count the total number of α -particles projected from one gram of radium per second. By determining the volume of helium produced by the collected α -particles, we have a simple and direct method of determining also the number of molecules in a cubic centimeter of helium at standard pressure and temperature. This number is in good agreement with the number found by Millikan by measuring the charge on the atom of electricity. On account of the great energy of motion a single α -particle can be detected in a variety of ways by the electrical method, by the scintillations produced in zinc sulphide or the diamond, and by its action on a photographic plate.

The most striking proof of the individuality of the electron, the α -particle, and the ion has been given by C. T. R. Wilson by his beautiful photographs showing the trails of α - and β -particles through gases. By a sudden expansion each charged ion produced by the flying particle is rendered visible by becoming the center of a visible drop of water. In the case of the swift electron, the number of ions per centimeter of path is so small that the number may be directly counted. These photographs bring out in a vivid and concrete way the phenomena accompanying the passage of ionizing types of radiation through gases, and are in a sense the ultimate court of appeal of the accuracy of theories of the properties of these rays.

The discovery of the electron and of the property of radioactivity has given a great stimulus to attempts to deduce the structure of the atom itself, and numerous types of model atoms have been proposed. The great difficulty in these attempts is the uncertainty of the relative importance of the rôle played by positive and negative electricity. In the model atom proposed by Sir J. J. Thomson the electrons were supposed to be embedded in a sphere of positive electricity of about the dimension of the atom as ordinarily understood. Experiments on the scattering of α -particles through large angles as the result of a single collision with a heavy atom showed that this type of atom was not capable of accounting for the facts unless the positive sphere was much concentrated. This led to the nucleus atom of Rutherford, where the positive charge and also the mass of the atom are supposed to be concentrated on a nucleus of minute dimensions. The nucleus is surrounded at a distance by a distribution of negative electrons to make it electrically neutral. The distribution of the external electrons on which the ordinary physical and chemical properties of the atom depend is almost entirely governed by the magnitude of the positive charge. The experiments by Marsden and Geiger on the scattering of the α -particles, and also on the scattering of X-rays by Barkla, show that the resultant units of charge on the

nucleus of an element is about equal to its atomic number when arranged in order of increasing atomic weight. Strong proof of the correctness of this point of view has been given by the work of Moseley on the X-ray spectra of the elements, for he has shown that the properties of an element are defined by a whole number which changes by unity in passing from one element to the next. It is believed that the lightest element, hydrogen, has a nuclear charge of 1, helium of 2, lithium of 3, up to the heaviest element, uranium, of charge 92.

Radioactive evidence indicates that the nucleus contains both positively charged masses and negative electrons, the positive charge being in excess. Apart from the difficulty on the ordinary laws of electric forces of explaining why the nucleus holds together there is a fundamental difficulty of accounting for the stability of the external electrons on the ordinary laws of dynamics. To overcome this difficulty Bohr has applied the quantum theory to define the position of the electrons and to account for the spectra of the lighter atoms and has made suggestions of the structure of the simpler atoms and molecules. Space does not allow me to discuss the important developments that have followed from Bohr's theory by the work of Sommerfeld, Epstein, and others. The generalized theory has proved very fruitful in accounting in a formal way for many of the finer details of spectra, notably the doubling of the lines in the hydrogen spectrum and the explanation of the complex details of the Stark and Zeeman effects. In these theories of Bohr and his followers it is assumed that the electrons are in periodic orbital motion round the nucleus and that radiation only arises when the orbit of the electron is disturbed in a certain way. Recently Langmuir, from a consideration of the general physical and chemical properties of the elements, has devised types of atom in which the electrons are more or less fixed in position relatively to the nucleus like the atoms of matter in a crystal. It appears necessary, in Langmuir's theory, to suppose that electrons, in addition to their electrical charges, are endowed with the properties of a magnetic doublet, so that at a certain distance the forces of attraction and repulsion between two electrons counterbalance one another.

The whole question of the possible arrangements and motion of the external electrons in an atom or molecule still remains a matter of much doubt and speculation. While there are strong indications that the conception of the nucleus atom is in the main correct, we are still very uncertain of the laws controlling the position of the external electrons on which the ordinary physical and chemical properties depend. The study of the light spectra and also of the X-ray spectra already promise to throw new light on this very difficult but fundamental problem.

From the above hurried survey of the progress of atomic physics it will be seen that the investigations of the past twenty-five years have dealt mainly with three great outstanding problems, viz, the nature of electricity, the structure of the atom, and the nature of radiation. While great additions have been made to our knowledge of these questions leading to a much wider outlook, we can not but recognize that much still remains to be done before we are certain that we are building on a firm foundation for the future. Notwithstanding the prolonged halt during the war, the scientific outlook is one of good augury for the immediate future, and there is every prospect that the vigorous attack on these outstanding problems will be continued.



THE HD-4 ON BADDECK BAY, PASSING AT FULL SPEED.

THE "HD-4."¹

A 70-MILER WITH REMARKABLE POSSIBILITIES DEVELOPED AT DR. GRAHAM BELL'S LABORATORIES ON THE BRAS D'OR LAKES.

By WILLIAM WASHBURN NUTTING.

[With 9 plates.]

One of the most interesting of the many strange things that have come from Dr. Graham Bell's laboratories is a weird-looking glider that recently has been tearing about the peaceful Bras d'Or Lakes at the rate of 70 miles an hour.

The *HD-4* is not a hydroplane in the usual sense of the term. It is the successful development of the idea, by no means new, of lifting the hull clear of the water by a system of submerged planes not a part of the hull itself. In other words, it uses the denser medium to obtain the lift and takes advantage of the low resistance to propulsion offered by the air. An ordinary hydroplane, of course, utilizes the lifting principle and dodges much of the resistance of the water, but it is still comparatively inefficient in that it uses only the lower and by far the less important surface of the plane.

A number of years ago Cooper-Hewett experimented with the idea of superposed planes and Forlanini attained some success with this principle in Italy. It is an alluring idea as the patent office records will show. But the *HD-4*, although she is only in the stage of development of the aeroplane of 10 years ago, is much more than a successful application of principle of lifting the hull clear of the water. You will notice from the detail pictures that the steel planes are arranged in sets like the rungs of a ladder and graduated from large ones at the top to small ones at the bottom. The faster the craft travels the more of the planes rise out of the water until only sufficient surface to carry the load remains submerged.

This automatic reefing of the supporting surface is one of the important features of the *HD-4* and one which, I believe, never has been attempted in an air craft, in which there is but one economical condition of speed and loading, a disadvantage particularly noticeable when taking off and landing.

¹ Reprinted by permission from Motor Boat, Vol. XVI, No. 20, Oct. 25, 1919.

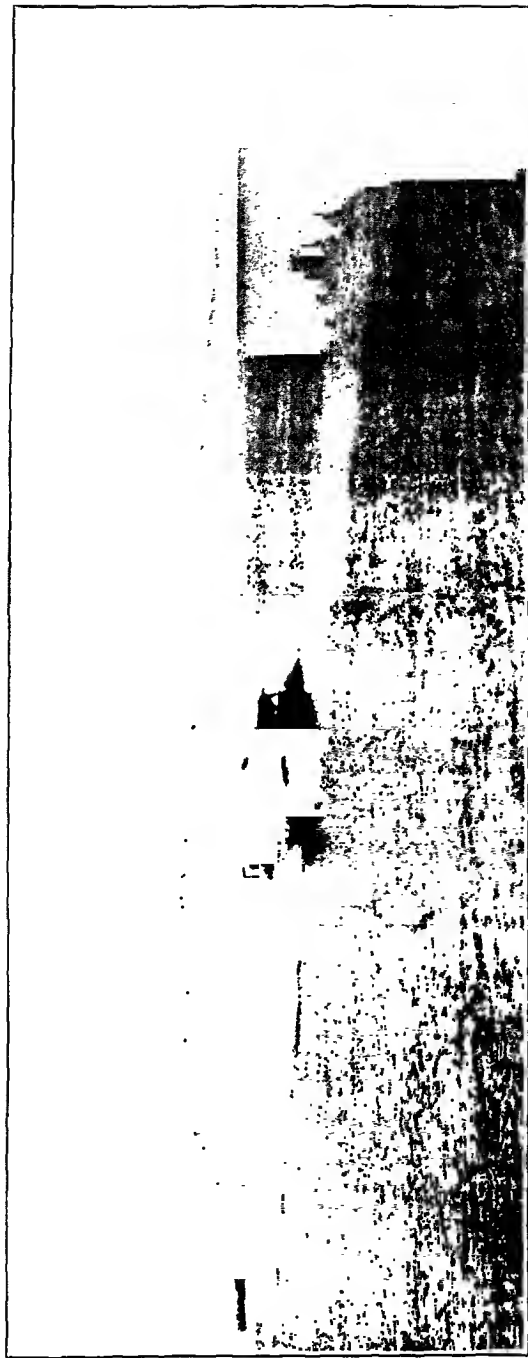
Now look at the planes again. You will notice that they are not set horizontally but have a slight lateral angle, or dihedral angle, as it is called in the parlance of the aeroplane. It was found in the early experiments that when the planes or hydrofoils were arranged parallel to the surface of the water, a noticeable irregularity occurred when changing speed or when traveling in choppy water, due to the effect of the entire plane entering or leaving the water at once. On the present machine the lower end of one plane is about on a level with the upper end of the plane below it and for this reason the reefing process becomes smooth and continuous. Furthermore, it was found that the dihedral angle of the hydrofoils greatly increased the stability of the machine.

The hydrofoils are arranged in three sets to give three point support like that of an ice boat, which obviates the twisting effect always present in a structure supported at four points. The fourth set shown at the bow, or "preventer," as it is called, is merely to keep the bow from diving and to help lift the machine when getting under way. At full speed it is entirely clear of the water.

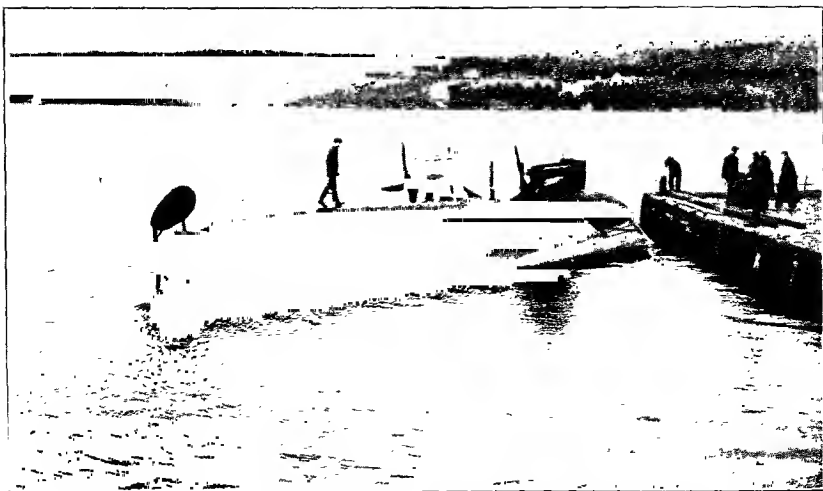
When looking at the planes for the first time, your impression is that they are ridiculously small to support such a large hull. But remember that the area of the supporting surface is in inverse proportion to the density of the medium in which it acts. The specific gravity of salt water is nearly 800 times that of air, which means that the area of the submerged hydrofoils need be but $\frac{1}{800}$ of the wing area of an aeroplane. It means also that the structural difficulties are insignificant compared to those encountered in aeroplane design, where the designer's troubles increase as the cube of the dimensions of his machine.

We said before that a surface hydroplane was inefficient in that it used only the lower and less important surface of the plane to obtain the lift. Few people seem to realize that it is the upper and not the lower face of the plane, say of an aeroplane, that does most of the work. The results made public recently by the British Advisory Committee on Aeronautics show that never, even with simple flat planes, does the air impinging on the lower surface exert more than a quarter of the total lift. It is the camber of the upper surface, over which a partial vacuum is created, that is the important factor. What is true of one medium is more or less true of another and, therefore, it would seem that a boat depending solely on the lifting effect of the water impinging on the sloping bottom is not the ultimate solution to the problem of obtaining speed on the water.

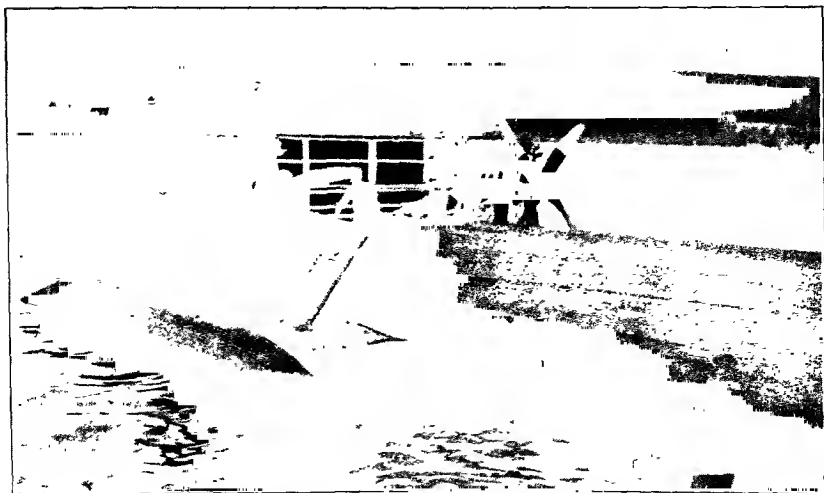
The steel planes of the *HD-4* are cambered according to the results of countless experiments, in order to take advantage of the lifting possibilities of both surfaces. The ratio of "lift" over



SEVENTY MILES AN HOUR ON BADDECK BAY.



THREE-QUARTER STERN VIEW OF HD-4 AT LABORATORY WHARF.



THE POWER PLANT ON THE HD-4.

"drift," that is to say, the ratio of the useful vertical component to the head resistance or horizontal component, is 8, whereas the best results thus far obtained with the surface hydroplane type, I believe, is about 6. In aeroplane work it is higher, but we are not claiming perfection for the *HD-4* at this early stage of its development.

The most efficient angle of incidence of the planes was a problem that was decided only after a long series of experiments. The highest ratio of lift over drift was obtained with the chord of the planes inclined at an angle of $1\frac{1}{2}^{\circ}$, which is used on the two forward sets. For the tail set it was found that the best results were obtained with the chord or flat under surface of the plane absolutely horizontal, which proves the contention that the under surface is comparatively unimportant.

At present the hydrofoil surfaces of the *HD-4* are supporting approximately 2,000 pounds to the square foot at 60 miles an hour, which is 200 times the load carried per square foot of wing area in aeroplane practice. What the limit is we do not know, as the subject is absolutely unexplored beyond this point. The theoretical limit to the lifting effect of the upper plane would be at the point where an absolute vacuum was created above it. Just below the surface of the water this would be slightly above 2,000 pounds per square foot, but the effect of another atmosphere could be obtained by submerging the planes to a depth of 32 feet which would be impractical.

It takes a thrust of about 2,000 pounds and a speed of about 20 miles an hour to get the hull clear of the water, beyond which point the thrust required drops to about 1,500 pounds and rises very slowly, due principally to the resistance of the air, the resistance of the water dropping from 1,900 pounds at 15 miles an hour to 1,300 pounds at 34 miles an hour and remaining practically constant above this point, due to the reefing of the supporting surfaces.

Since this article was written the writer has received from Mr. Baldwin the following interesting data:

When the main set of hydrofoils is set at an angle of $1\frac{1}{2}^{\circ}$ and the rudder set at 0° the machine rises at about 20 miles per hour on roughly 40 square feet of surface, which equals about 275 pounds per square foot. At 40 miles per hour about 10 square feet of surface are immersed, which equals 1,100 pounds per square foot, and at 60 miles per hour the entire machine is carried upon about 4 square feet of surface, or 2,470 pounds per square foot of hydrofoil immersed.

Now that we have explained the theory, let us look over the machine itself. The hull of the craft is a torpedo-shaped affair 60 feet in length, with two outrigger hulls or pontoons each 16 feet in length connected to the main hull by a deck. The deck supports the two Liberty motors, which are mounted on either side just abaft the cockpit. It is designed in the form of an aerofoil, with flat under surface

and cambered top and presenting a useful lifting area of 203 square feet.

The hull is 5 feet 9 inches in diameter and is quite heavily built. A system of fore-and-aft stringers are secured to several bulkheads and the frame is a continuous spiral wrapped around these. The half-inch planking is applied longitudinally and, to resist bending and torsional stresses, a number of longitudinal and diagonal steel wires are run over the frame. The hull is covered with canvas laid spirally in the opposite direction to the framing. Except for the cockpit and a fuel tank in the stern, the hull is unused and would accommodate a score of people.

The forward hydrofoil sets, upon which the machine largely depends for support when under way, are hung on a steel tube 5½ inches in diameter, which passes through the hull 15 feet from the bow. The tail set acts also as a rudder, the struts offering sufficient lateral surface for this purpose. It is mounted on a column 6 feet from the stern and is operated by tiller lines running to the steering wheel in the cockpit.

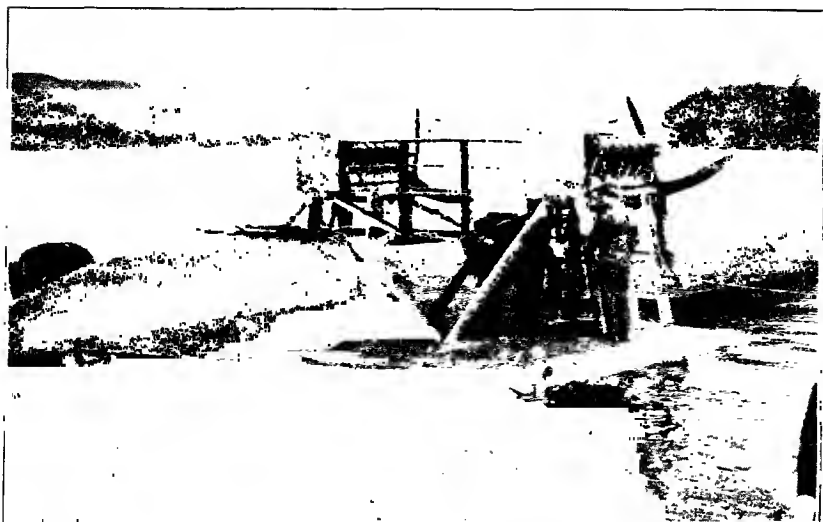
The motors are of the low-compression Liberty type, developing 350 horsepower and weighing 800 pounds each. They are mounted on a special form of wooden trussed bed, the horizontal members of which are finished in the form of aerofoils, adding a useful lifting surface of 83 feet. The function of this surface and that of the deck is to provide an air-cushioning effect which acts as a sort of shock absorber when the machine is traveling in choppy water.

The motors are provided with compressed-air starters and all controls are led to the cockpit. The fuel is forced from the tank in the hull to the level of the carbureters by air pressure maintained by a hand pump.

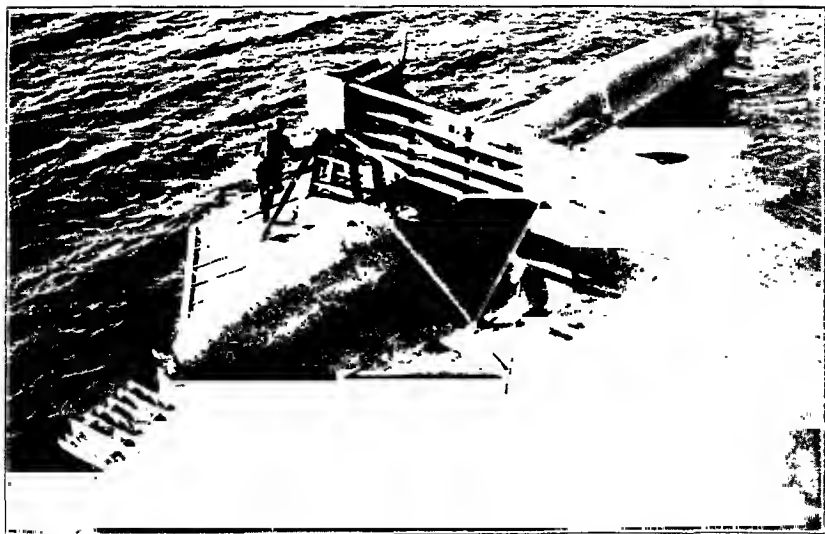
The center of gravity of the machine is 25 feet from the bow, but when she is running at full speed the line of thrust of the air propellers is 10 feet above the base of support, which brings the virtual center of gravity about 23 feet from the bow.

Now step into the cockpit and we will take a ride, and if you want to hear anything for the rest of the day stuff some cotton into your ears before the motors are started, for they are not muffled. Over goes the starboard motor with the crackle of a machine gun and those on the dock scurry from the cyclone caused by the whirring propeller. The mooring lines are cast off and we slip out into the lake at about 10 knots.

Baldwin gives the air to the port motor and the exhaust becomes a continuous roar. At 15 knots you feel the machine rising bodily out of the water, and once up and clear of the drag, she drives ahead with an acceleration that makes you grip your seat to keep from be-



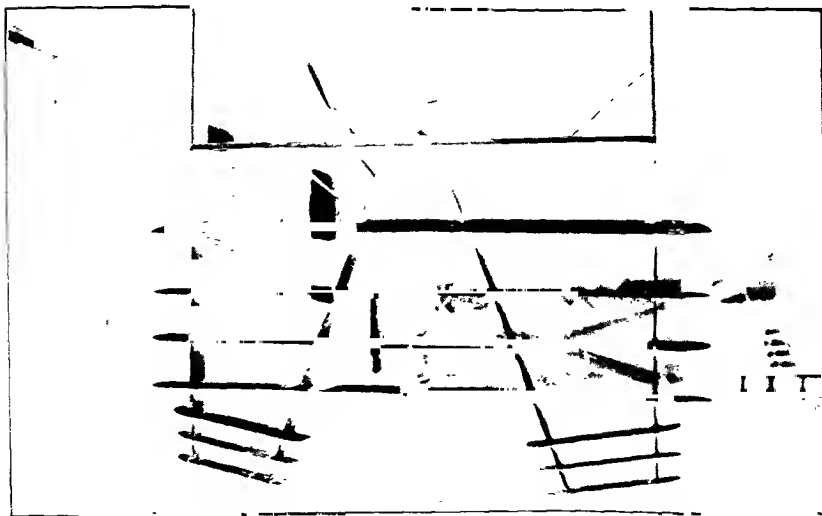
THE HD-4 ENGINE MOUNTINGS: TWO LIBERTY LOW-COMPRESSION MOTORS,
350 HORSEPOWER EACH.



THREE-QUARTER BOW VIEW OF THE HD-4 FROM ABOVE.



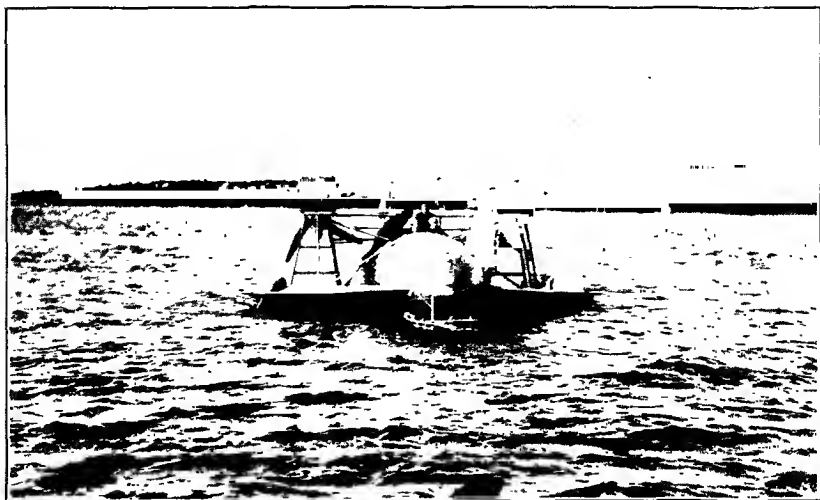
BOW VIEW OF THE HD-4 ON HER CRADLE, SHOWING STARBOARD AND PORT HYDROFOILS.



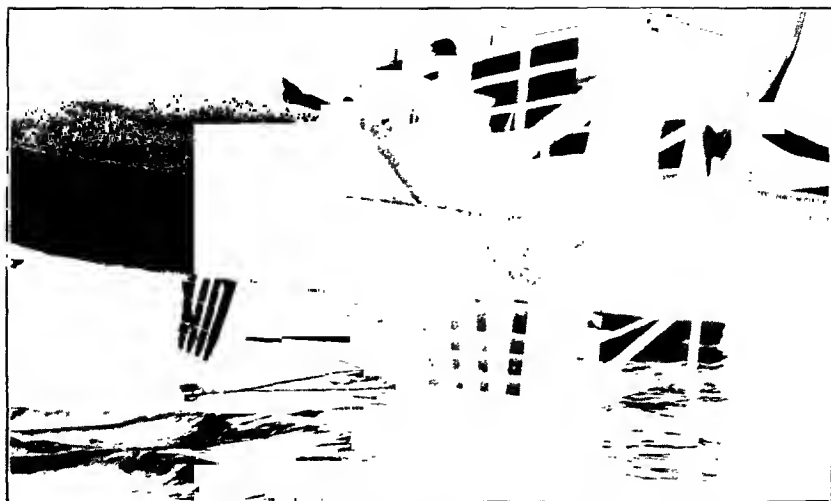
REAR VIEW OF THE HD-4 IN HER SHED, SHOWING STERN HYDROFOILS.



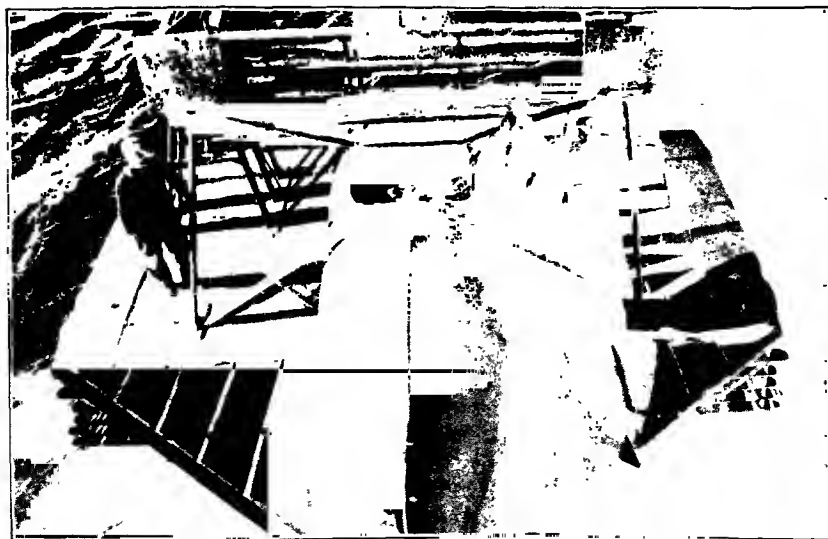
DR. BELL AT THE LABORATORY WHARF, WATCHING THE PERFORMANCES OF
THE HD-4 ON BADDECK BAY.



THE HD-4 FLOATING AT REST ON BADDECK BAY.



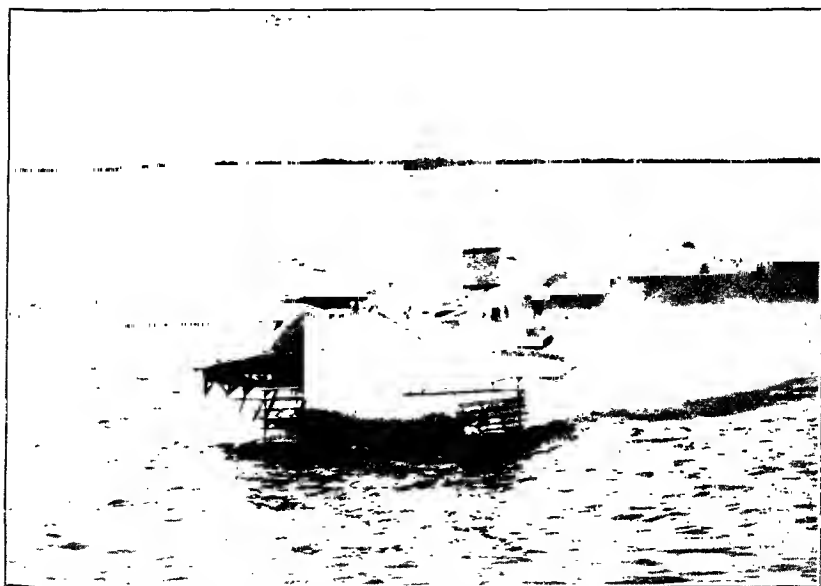
THE HD-4 ON HER HAULING-UP CRADLE, SHOWING MAIN HYDROFOILS FROM THE SIDE.



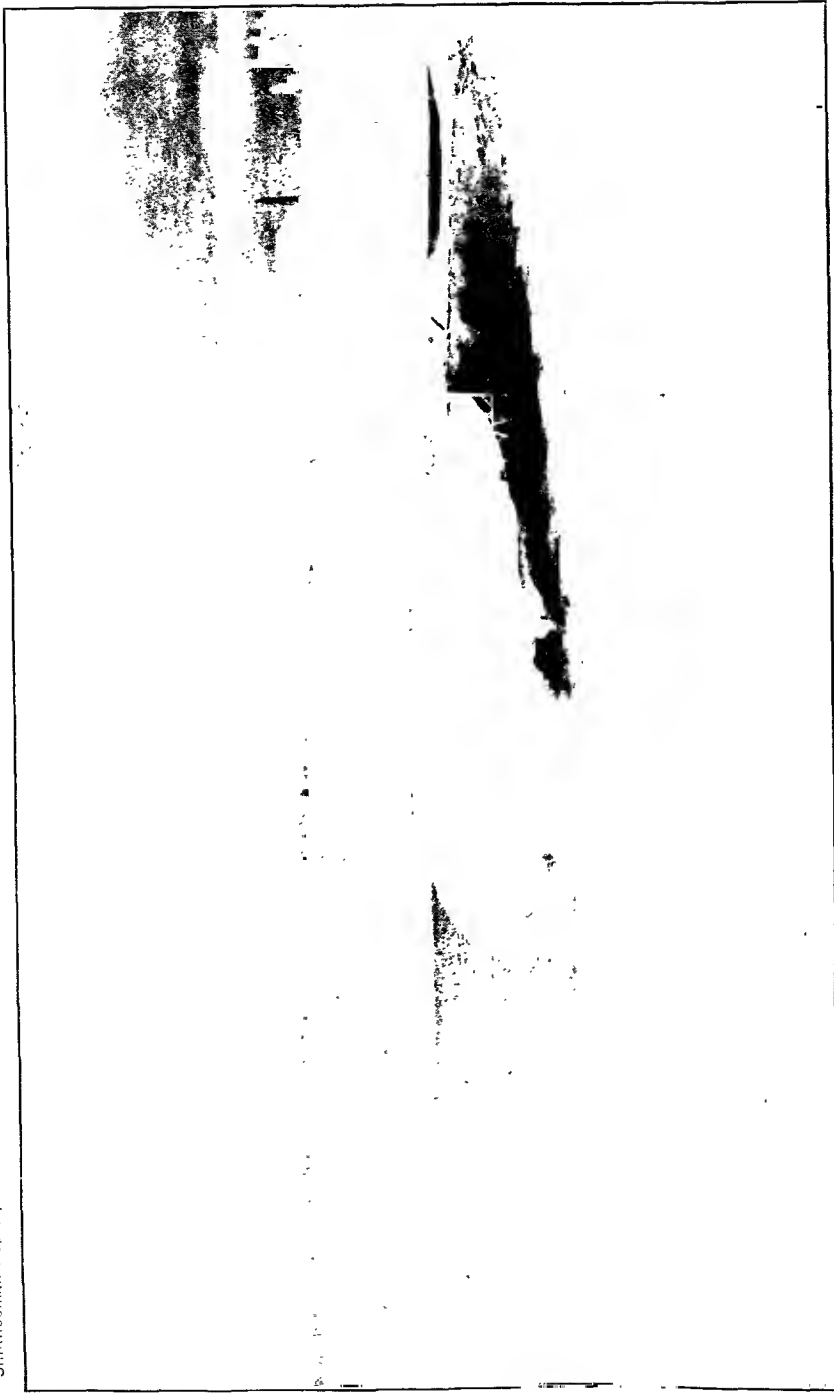
BOW VIEW OF THE HD-4, SHOWING DECK AND COCKPIT ARRANGEMENTS.



COCKPIT OF THE HD-4: DR. BELL, MR. BALDWIN AT THE WHEEL, AND THE CREW.



SHOWING HOW FAR OUT OF THE WATER THE HD-4 RIDES WHEN AT FULL SPEED.



THE HD-4 TURNING AT HIGH SPEED.

ing left behind. The wind on your face is like the pressure of a giant hand and an occasional dash of fine spray stings like birdshot.

Baddeck, a mile away, comes at you with the speed of a railway train and you brace yourself for the turn as Baldwin drives her through the narrow passage inside the island. You feel that she is going to skid as he starts to make the turn at full speed, but she does not. Just as the struts of the rudder set are sufficient to steer her, so are those of the main planes sufficient to keep her from side slipping. Even more startling is the fact that she doesn't seem to heel a degree as she makes the turn. It is unbelievable—it defies the laws of physics, but it is true.

Then you notice that you are traveling over waves a foot and a half in height—waves that would take the bottom out of an ordinary hydroplane traveling at such a speed. There is no pounding or jolting of the kind with which everyone who has ridden in a racing hydroplane is familiar. A slight undulation like that you feel in a Pullman car is the only sensation.

Another noticeable thing is that when hitting a wave there is no retarding of the machine as would be the case with a surface plane, and in this connection it might be interesting to note the effect on the hydrofoil supports at top speed. It will be seen from plate 7, figure 1, that the forward hydrofoil sets are hung from a steel tube which passes through the body of the machine and that the axis of the struts is several inches forward of the center of this pipe. This seemingly insignificant length of lever arm through which the "lift" is applied is sufficient to neutralize the "drift" on the hydrofoils 3 feet or so below the point of support. At full speed, instead of a tremendous backward pull on these struts as would be expected, the tendency is actually forward, and the supporting member running from the strut to the under side of the deck, instead of being in tension as would be expected, is actually in compression.

Then Baldwin gives you the wheel and timidly you start to try it out. You feel that something must surely let go if you give her any helm. But nothing does and you find that she steers with the ease of an automobile.

As you get accustomed to the speed your confidence grows and soon you find yourself out of the cockpit lying over the edge of the deck on your stomach to see for yourself what is going on below. The "preventer" at the bow is entirely clear of the water except for the tip of an occasional wave and all of the main sets are out except for the two lower ones on either side. Each square foot of submerged steel is carrying over 2,000 pounds.

Baldwin designed the *HD-4* to demonstrate the possibilities of the type for carrying loads at extreme speed, efficiently, and with com-

parative safety. When you come in from your first ride you are convinced. If you have ever flown, you know that flying is a dull business, compared to skimming over the surface of the water at 60 knots, and for this reason there undoubtedly will be a future for the type for sport as well as for the more serious things at which Dr. Bell and Mr. Baldwin have been aiming.

NATURAL RESOURCES IN THEIR RELATION TO MILITARY SUPPLIES.

By ARTHUR D. LITTLE.

In the aboriginal days, when the American Navy consisted of birch-bark canoes manned by Indians, the relation of the canoe to the birch tree was obvious. Even in that far-off and simple time, however, the problem of securing suitable material for the arrow-head with which the Indian tipped his shaft was by no means simple, and its solution frequently involved long journeys and the use of diverse materials. The Indians of what is now New England evidently used the black flint from Mount Kineo, but Middle West Indians used obsidian, much of which probably came from the Yellowstone district. Indians along the lower Colorado River made myriads of arrowheads from flint cobblestones, very like those which practically cover the surface of the ground between Kingman and the Grand Canyon. Florida Indians used colored silica, most of which is pseudomorph after oyster shells and coral, and in some parts of the West there may be found arrowheads of petrified wood. The southeastern part of the country abounds in heads made from white quartz or quartzite.

In a word, the Indian on the warpath, like all other belligerents before or since, found his warlike activities conditioned and determined by the natural resources of his environment and his own technical ability to make use of them. He fought with flint arrowheads over beds of coal and iron ore because he knew nothing of smelting iron, and so, for his military purposes, the continental reserves of coal and iron ore were nonexistent.

In the same measure that our present civilization exceeds in complexity the primitive life of the savage do the requirements of modern warfare bring new demands which strain all the resources of that civilization, and may even, as we have witnessed, strain them beyond the breaking point. In the last analysis the capacity of a nation to wage war is determined by the natural resources available to that nation and the technical ability and productive agencies which it can utilize in their conversion into military supplies.

We all recognize the fundamental importance in this connection of such basic natural resources as coal and limestone and iron ore, but

we may overlook the fact that the addition of a small percentage of tungsten to the steel of cutting tools may multiply by four the output of a mechanic making machine-gun parts. It was not immediately obvious that the success of a gas-mask program and all the consequences of a failure of that program might hinge on the supply of coconut shells from which to make absorbent charcoal. Only recently has the atmosphere become our most reliable source of nitrates. Seaweed might be regarded as a negligible resource from the military standpoint, but the war called into being at San Diego a vast plant producing from Pacific kelps iodine, potash, and a whole series of organic solvents required in the powder manufacture. The mitsumata plant, from the bark of which the Japanese make their paper, is less belligerent than a humming bird, but it contributed the 3,000,000 paper parachutes with which our star shells were provided. Nearly 500,000 Chinese Nuchwang dogs gave up their hides and fur to keep our aviators warm, and millions of Australian rabbits "went west" because their furry coats were needed to make the hats our soldiers wore. We do not go to a gun store for bird seed, but bird seed is none the less a military supply. The Signal Corps trained 15,000 carrier pigeons for service in France, and tons of Argentine corn, pop corn, millet, and Canada peas were shipped to feed them. Incidentally, it may be said that the pigeons delivered over 95 per cent of all the messages intrusted to them.

To a layman like myself it begins to be apparent that any consideration of the relation of raw materials to military supplies involves some extension of commonly accepted notions as to what military supplies really are.

At the beginning of 1919 the catalogue of Army supplies comprised 120,000 separate items. On the day the armistice was signed nearly 8,000 manufacturing plants in the country were working on ordnance contracts, and the estimated total cost of ordnance alone for the equipment of the first 5,000,000 American soldiers was between \$12,000,000,000 and \$13,000,000,000, and involved expenditure at a rate which would pay for a Panama Canal every 30 days. The Wool Administrator did a business of \$2,500,000 a day, and the total purchases of wool reached \$504,000,000. The war demand absorbed substantially all the wool in sight, leaving practically nothing for civilians, and this shortage was felt with varying degrees of acuteness by all the belligerents. In fact, the only country in the world that had an excess of wool in November, 1918, was Australia, which was surfeited with an accumulation of a billion pounds, to export which no shipping was available. Twenty-two million blankets were provided to keep our soldiers warm, and 100,000,000 yards of Melton cloth for overcoats and uniforms. In the Chicago district

alone hundreds of shirt factories were making flannel shirts on Government contracts, and throughout the country some 4,000 inspectors were assigned to garment factories.

Of cotton textiles we procured in all over 800,000,000 square yards. The figure is impressive as it stands. It becomes preposterous when a brief calculation shows that if laid out in a 1-yard width 55 globes the size of the earth might be placed upon it. Among the items which make up the total were 100,000,000 yards of denim, 120,000,000 yards of webbing, 140,000,000 yards of gauze, and nearly 300,000,000 yards of cotton duck. An especial interest attaches to cotton webbing because of its very general substitution for leather in countless details of equipment, as cartridge belts, suspenders, gun slings, and horse bridles. So great was the demand that ultimately 150 plants were engaged in webbing production, and there was a very serious shortage throughout the war of machine knitting needles for webbing, hosiery, and gloves, these needles having formerly been made in Germany. As an example of the relation of design to emergency production it may be pointed out that there were not enough machines in the United States to knit one-tenth of the seamless woolen gloves required, in consequence of which the gloves had ultimately to be redesigned and made from knit fabric, cut to pattern and sewed. These did not wear well, and it became necessary to supplement them with another glove of cotton flannel with a leather palm to be worn outside the woolen glove.

In the variety and multiplicity of its applications to military requirements cotton stands forth as a basic raw material comparable at least in its importance to steel. It was ubiquitous and protean. It flowed in an unceasing stream through thousands of factories and plants to reappear in camp and field and hospital as underwear, clothing, tents, bed rolls, and sheeting; barrack bags, coal bags, and mail bags; cargo and wagon covers; mask fabrics, tire and hose fabrics. It functioned high above the field of battle as balloon fabric and the cloth for airplane wings. It constituted the base of all our smokeless powder and of the dope for airplane wings. It supplied both the base and the coating material for the artificial leather essential to automobile construction. To the surgeon and the wounded man it was indispensable as gauze, absorbent cotton, and collodion, and for them it provided in one year 574,000,000 yards of bandages. Supplemented with rubber and paraffin, it insulated the 40,000 miles of outpost wire required to satisfy the monthly needs of the Signal Corps. The millions of steel helmets were lined and meshed with cotton twine. In the form of celluloid film cotton bore the countless pictures which carried information of vital importance and registered the story of the war.

The millions of pounds of smokeless powder produced each day in Government and private plants were not made from staple cotton, but from the shorter cotton linters, together with the very short fibers adhering to the cotton hull, and our production of propellants thus made no demands upon the store of cotton suitable for textile purposes.

Before leaving the textile fibers we may, to hold our subject together, mention that 216,000,000 buttons were required in one year for Army shirts alone. Their raw material was ivory nuts, and the waste was converted into charcoal for the gas-absorbing canisters of the gas masks. Only a very dense and hard charcoal functioned adequately, and for this we at first depended upon coconut shells. Our demands quickly rose, however, to about five times the entire coconut production of the tropical Americas. Cohune nuts were next utilized, and from them the exigencies of gas defense spread the demand to peach stones, ivory nuts, olive and cherry pits, and even to Brazil "where the nuts come from." At one time there were on the rails 100 carloads of peach stones and similar materials moving to the carbon plants. We made in all $5\frac{1}{4}$ million gas masks, and the failure in supply of such a thing as coconut shells might have lost the war.

The American soldier was blessed with a good appetite and ate nearly three-quarters of a ton of food a year. He consumed during the war period over 1,000,000,000 pounds of flour and 800,000,000 pounds of beef, and we must not forget that behind the flour mills stood vast wheat fields or that only wide cattle ranges could daily fill the stockyards. We may omit the other imposing items of the gigantic meal, for which the total bill was over \$700,000,000, but it should be noted that in it were included the widely varied contents of tin cans to the number of more than a billion. The tin can in its humble way marks the range of civilization, and he who has gone beyond the last tin can is an explorer of the unmarked wilderness. It defines equally the range of armies and the penetrating influence of the Standard Oil Co. In the same sense that Napoleon's armies traveled on their stomach modern armies mark their progress by the tin cans they leave behind. It is significant, therefore, that the United States normally consumes about 70 per cent of the world's production of tin, to which it contributes practically nothing, and half of this production goes into tin plate. As Germany neither produced nor could secure tin she was forced to substitute cardboard containers or to resort to dried foods.

One bakery had a capacity of 500,000 pounds of bread a day, and contracts were made for 15,000 complete rolling kitchens, including of course cooking and camp utensils, with which may be mentioned the inconspicuous item of 10,346,000 spoons. Even less pretentious

as a military supply, but of substantial importance is the garbage, from which the British extracted glycerine at a saving of \$1,000 a ton.

To furnish drinking water on the march provision was made for 22,000 drinking water carts, in many of which the water was carried in canvas bags, while to remove delinquent members of the soldier's dental equipment the horrors of war were increased by the activities of more than 47,000 teeth-extracting forceps. The other side of the picture may be indicated by the solace afforded by shipments of a monthly average of 20,000,000 cigars, 425,000,000 cigarettes, and a ration of candy which involved $3\frac{1}{2}$ million pounds in a single month. Even chewing gum found its place as a military supply of recognized and great value on the march as a substitute for water.

The building program forced upon us by the war involved thousands of structures to meet the most diverse requirements and a far greater expenditure than that of all the construction operations in 150 of our largest American cities in any single year. Sixteen complete cities, each ready for 40,000 inhabitants, and 16 tent camps were completed in less time than it takes to build an ordinary suburban dwelling house. In little more than a year new housing had been provided for a population equal to that of Philadelphia. Forty bed hospital wings were erected, painted, equipped, and plumbed in 10 hours. At Nashville, Tenn., and at Nitro, near Charleston, W. Va., vast industrial plants, designed in the one case for the production of 1,000,000 pounds and in the other for an output of 625,000 pounds of smokeless powder per day were built, equipped, and put in operation with extraordinary speed.

Houses went up to the value of \$2,000,000 a day. All this means a flow of construction material without parallel in the history of the world. Lumber and wall board, window glass and roofing, nails by the billion, brick and cement and structural steel—all to a total of millions of tons—took their place in the finished structures. All the factories in the United States could not meet the demands for metal piping. But the cantonments were merely an incident in the building program, which included also enormous powder plants, huge terminal docks, warehouses and storage depots covering almost 900 acres, hundreds of miles of railroads, proving grounds, arsenals, chemical plants, and more than a thousand miles of road.

The supplies required for the health, comfort, and diversion of our troops were of the most miscellaneous character, ranging from raincoats, slickers, and 4,000,000 pairs of rubber boots to furs for the Siberian expedition. They included 200,000 sheets of band music and 143,000 musical instruments. The requisition for 500,000 pillows disclosed a shortage in feathers, and after the ducks in the United

States had made their contribution it was not even possible to secure an adequate supply from China. Jam brought variety to the soldier's ration, but the 26,000,000 pounds consumed carries a suggestion of monotony. Fifty-nine factories in the United States operated at emergency speed to supply the 9½ million brushes needed, and China, India, Russia, and Siberia were drawn upon for bristles. The 45,000,000 safety razor blades constituted a minor, but essential item of supply and recall the story of the negro trooper, who, finding a safety razor in the comfort bag which he received from some well-intentioned organization, was heard to remark, "I wonder what damn pacifist put that in."

Hospitals with 280,000 beds were made ready and available in France, and the amount actually spent for medical supplies was over \$370,000,000. A single item covered 300,000,000 tubes of iodine-potassium. In one month there were shipped 65 tons of surgical instruments to France, and during the war over 1,000,000 clinical thermometers were supplied. It is interesting to compare the estimated medical requirements of an army on a peace and war footing, a peace quota of 500,000 men being adequately supplied with an expenditure of about \$9,000,000, whereas on the war basis 5,000,000 men necessitated an annual expenditure of nearly \$306,000,000. In other words, the expenditure per man is about three and one-half times as great on the war basis as during a period of peace.

The problem of transportation of military supplies is obviously as important as that of their procurement. It is a matter of common knowledge that the railroad facilities of the country broke down under the strain imposed upon them and have, in fact, not yet recovered therefrom. However this may be, transportation from the terminals to the front must in nearly every case depend ultimately upon motor trucks, and of these the army had in the latter part of 1918, 85,000. Had the war lasted until July 1, 1919, there would have been in commission 185,000 trucks, 30,000 motor ambulances, 40,000 passenger cars, and 70,000 motor cycles. To them gasoline, of course, stood in the relation of powder to the gun and was latterly consumed at the rate of about 200,000 barrels a month, including that assigned to Army planes. For these there was provided a special redistilled gasoline, known as "257° Fighting Naphtha," which, to avoid waste and misuse, was dyed red.

However one may feel about the horse, the mule is generally regarded as raw material. In two years the Army purchases of horses were over 300,000, and more than half as many mules were brought into service. For these fodder, feed, and veterinary supplies were obviously required in great amounts, and the former were, of course, derived directly from the soil.

The chief materials for smokeless powder are cotton linters, sulphuric and nitric acids, and various organic solvents, as, for example, acetone in the case of cordite. The shortage of cotton, which early developed in Germany, forced that country to substitute for cotton chemically-prepared wood fiber. A wider range of raw materials is available for the production of high explosives, in which are utilized toluol, phenol, and aniline among organic compounds and sodium nitrate, sulphuric acid, nitric acid, and ammonia liquor among the inorganic substances most directly concerned. Nothing in the record of American industry is more striking and creditable than the enormous expansion of our output of explosives to meet the exigency of the war. In 19 months our production of propellants was 632,504,000 pounds, an amount practically equal to the combined production of the British and the French. During the same period we made over 375,000,000 pounds of high explosives.

The sulphuric acid concerned in such production is made from pyrites or from sulphur. The greatest producer in the world—at Ducktown, Tenn.—utilizes, by subsequent oxidation, the sulphurous acid in its smelter fume. Many domestic plants depended upon pyrites from the Rio Tinto district in Spain, and this supply was quickly shut off by the war. We have, however, in Louisiana and Texas the greatest known deposits of sulphur in the world, and these were largely drawn upon. The danger of a highly localized supply was emphasized when early in 1918 a destructive storm crippled the Louisiana producers, but fortunately the damage was repaired before the acid makers were affected.

Coal is practically the only source of toluol, from which it is commonly derived through the agency of by-product coke ovens. In 1914 the total toluol capacity of such ovens in this country was only about 700,000 pounds a month, and the necessity for a greatly increased supply for conversion into trinitrotoluol or T. N. T. presented one of our greatest and most pressing problems in raw materials. So well was it met, however, that by April, 1917, our production had risen to 6,000,000 pounds a month, and this monthly output was doubled by November, 1918. Much of this increased supply was due to the expedient of stripping city gas by washing out the toluol, and additional supplies were secured by the development of methods of cracking petroleum oils.

Trinitrotoluol was early recognized as perhaps the most important of the high explosives, and the courage and initiative of our private manufacturers brought our production up to 16,000,000 pounds a month. Meantime two great Government plants were built: one at Racine, Wis., with a capacity of 4,000,000 pounds a month, and the other at Giant, Calif., designed for 2,000,000 pounds

a month. These did not, however, become actual factors in production. In addition to its widespread use in high-explosive shells T. N. T. figured both spectacularly and effectively in airplane bombs, some of which carried 500 pounds.

Of phenol—also a product of the distillation of coal—the base of trinitrophenol or picric acid, our monthly production was raised from 670,000 pounds upon our entry into the war to 13,000,000 pounds a month 19 months later, and of this a considerable proportion was produced synthetically from benzol.

Picric acid, which is made from phenol by treatment with nitric and sulphuric acids, constitutes the chief explosive used by the French, who found it necessary to call upon us for vast amounts, and in response to this demand our production rose in 12 months from 600,000 pounds a month to 11,300,000 pounds, an increase of 2,000 per cent. Our own Government authorized the construction of three picric acid plants, each of a monthly capacity of $14\frac{1}{2}$ million pounds. Only one, however, went into production before the signing of the armistice.

The raw-material relation of ammonium picrate is obvious, as is that of tetranitroaniline, which we produced in quantity for Russia for the loading of boosters and fuses. Tetryl or tetranitrodimethylaniline was only used as a loading charge for boosters, but was, however, being turned out at the rate of 160,000 pounds a month when the armistice was signed.

All this vast production of explosives was, of course, conditioned upon the maintenance of an adequate supply of nitric acid, which essential had formerly been derived from Chile in the shape of sodium nitrate. A gigantic program for the fixation of atmospheric nitrogen in various combinations was thereupon conceived and pressed into execution. At Sheffield, Ala., a great plant for producing ammonia by a modification of the Haber process was just coming into production at the signing of the armistice. The cyanamid process was installed on a grand scale at Muscle Shoals, Ala., which was starting production at the same time. Elsewhere the Bucher process of making sodium cyanide was under development. On November 11, 1918, the total producing capacity of the country for ammonium nitrate from all sources, including Muscle Shoals and Sheffield, was 20,000,000 pounds a month.

Among the most notable of the great constructive operations of the war must be mentioned the Old Hickory plant for smokeless powder at Nashville, Tenn., the somewhat smaller but still vast plant at Nitro, and the enormous expansion of private plants, as that of the du Ponts at Hopewell, Va. The Old Hickory plant was self-contained and comprised nine complete powder lines, each of a capacity

of 100,000 pounds a day. It covered 5,000 acres, involved the construction of a city of 20,000 people, and cost in all some \$90,000,000. There the War Department found itself engaged in building churches. The Nitro plant had a daily capacity of 625,000 pounds.

The United States was the only combatant to use nitro starch, which was employed in the loading of hand and rifle grenades and trench mortar shells. Reference should also be made to the utilization of mercury in the explosive program through its employment as mercury fulminate in detonators and primer charges.

In addition to the immense amounts of steel required by the Navy for ships, armor, and guns of all sizes, the Army ordnance included various types as follows: Two-man 37-millimeter cannon, mobile field guns of 75-millimeter caliber, 155-millimeter howitzers, 4.7, 5, 6, 8, and 10-inch field guns, and 12 and 14-inch rifles on railway mounts. All these were required in great numbers—thousands of the smaller arms and hundreds and scores of the larger. Preeminent as we are in the steel industries, all the facilities of the country were inadequate to realize the gun-building program. It was, therefore, to be supplemented by a vast ordnance plant, greater than the Krupps, on Neville Island in the Ohio River near Pittsburgh. This was designed to complete each month 15 great 14-inch guns and simultaneously to carry forward toward completion hundreds of others, while turning out at the same time 40,000 projectiles monthly. The plant was equipped to build 16 and even 18 inch guns, the latter weighing 510,000 pounds each. Work on this gigantic construction project was suspended at the signing of the armistice and was abandoned soon thereafter.

The amount of steel required for artillery is well indicated by our replacement agreement with France, under which we supplied for artillery furnished 6 tons of steel for each 75-millimeter gun, 40 tons for each 155-millimeter howitzer, and 60 tons for each 155-millimeter gun. There must also be considered the immense amount of material tied up in machine tools and special steels required for the fabrication of guns, rifles, and projectiles. In fact, the machine tool supply was never adequate, and the most drastic measures were justified in its requisition.

It is interesting to note that it takes 10 months to build a 14-inch gun, the life of which at the normal rate of firing is 150 shots before relining. Since each shot is executed in one-fiftieth to one-thirtieth of a second, the actual life of the gun in the actual performance of its function is only 3 seconds long. For instantly destroying the effectiveness of captured cannon we used thermite grenades for fusing their firing mechanism.

The steel for gun manufacture must obviously be of the highest quality and finest grade for its intended purpose and is often an alloy

steel, like nickel steel. It is smelted in open-hearth furnaces, the charge for which consists of pig iron and selected scrap. Over 21,000 workmen were employed in big-gun construction and as many more in the fabrication of gun carriages and fire-control instruments. Each carriage, moreover, in the case of mobile guns, required a shield of armor plate. In 1918 we produced over 8,400 cannon forgings. As regards the effective weight of the guns themselves, it is significant that the 800-pound gun of nickel steel of 1918 fires as heavy a projectile as the 1,650-pound bronze gun of the Napoleonic wars.

Each gun required an immense amount of heavy equipment, mostly, of course, of steel in the form of limbers, caissons, auto trucks and tractors, caterpillar mounts, and other devices. Each 155-millimeter howitzer involved some 200 items of miscellaneous equipment, as air and liquid pumps and tools. All this required the erection of great base repair shops—in themselves larger than some producing arsenals.

The extraordinary development of barrage fire by which the war was characterized was conditioned on the use of thousands of delicate and accurate sighting instruments and involved the expenditure of ammunition in quantities hitherto unknown. The Union Army at Gettysburg fired 32,781 rounds. The United States fired at St. Mihiel over 1,000,000 rounds and the British at the Somme 4,000,000 rounds. In the Civil War Union artillerymen fired 4 rounds per gun per day, whereas from January 1 to November 11, 1918, the average for American guns was 30, for French 34, and for British 35 rounds per day.

As to shell production, we turned out prior to the armistice, and in the 75-millimeter size alone, about $4\frac{1}{4}$ million high-explosive shells, one-half million gas shells, and over $7\frac{1}{4}$ million shrapnel.

The various sorts of grenades made, of course, wholly different demands upon raw materials for their construction. The defensive or fragmentation type was made of malleable iron; the offensive grenade had a paper shell, its purpose being to kill by the concussion of the charge; gas and phosphorus grenades were formed of sheet metal and the thermite shell of terne-plate. And there were also incendiary and rifle grenades. About 28,000,000 of all kinds were produced by November, 1918, but only a small proportion—less, indeed, than 4 per cent—were loaded. Contracts had been placed for 68,000,000 of the defensive type alone.

At the time of the armistice the standard equipment of a division called for 260 heavy machine guns and 768 light automatic rifles, and the total of automatic arms made on army orders alone in the United States and Canada was over a quarter of a million. About 32,000 Lewis aircraft guns were completed. It was found neces-

sary to provide over 280,000 rounds of ammunition per machine gun in the field during its first year of service.

It will be remembered that the question of shoulder rifles occasioned much discussion and concern, but the United States nevertheless built in 19 months over two and one-half million of these weapons and about 750,000 pistols and revolvers and turned out in the same time nearly 4,000,000,000 rounds of small arms ammunition, including that for machine guns. In view of these great figures it is interesting to consider them with respect to the materials concerned in the make-up of some of the units of this ammunition.

The ordinary service cartridge consists of a brass cartridge case, a primer with a primer charge of sulphur, chlorate of potash, and antimony sulphide, a propelling charge of smokeless powder, which refers at once to cotton and the fixation of atmospheric nitrogen, and finally, a bullet with a cupro-nickel jacket and a lead slug or core. The production, therefore, of this single small object involves our reserves of copper, zinc, nickel, lead, and antimony among the metals; the Louisiana or Texas sulphur deposits; potash, as to which we were experiencing a famine; water power to convert by electrolysis potassium chloride to the chlorate; and finally, cotton linters, sulphuric and nitric acids, various organic solvents, and even the fixation of atmospheric nitrogen. Since there was a shortage in cupro-nickel, which is a hard alloy of the two metals, it might have become necessary to have jacketed the bullet with copper-coated steel.

The armor-piercing bullet had a cupro-nickel jacket lined with a thin lead coat, and the core was of specially heat-treated alloy steel. Tracer bullets, of which 5,000,000 were produced, had a cupro-nickel shell with a lead core in the nose and a rear chamber charge of barium peroxide and magnesium, the latter being an electric furnace product. The shell of the incendiary bullet was the same, but it carried phosphorus in the nose, had a lead plug, and a special, low-melting solder.

The trench mortar from the 3-inch Newton-Stokes to the 240-millimeter was an interesting and highly effective development of the war. The 3-inch mortars and the shells used therein were both made of steel tubing, and for the latter alone about 2,700,000 feet of such tubing were made. Shells for the 6-inch mortars were of cast iron and made by stove manufacturers.

The revival of the use of armor, which, of course, requires for its fabrication alloy steel of the highest quality, was no less significant and interesting. Good alloy steel 0.036 inch thick proved effective against pistol bullets, and French hospital records show that 70 to 80 per cent of the wounded soldiers received were injured by mis-

siles or shell fragments which armor like this would have stopped. The Germans made much use of body armor, and our own Government went to the great art galleries for specialists in armor in its effort to produce helmets affording the utmost measure of protection. Our highest ambition was to rival the product of the best armorers of the Middle Ages, over whom we had a great advantage in the superior qualities of modern special steels. Steel containing much manganese was found best adapted to use in helmets and was used also in the British helmet. Of 7,000,000 helmets ordered we received 2,700,000. It is curious to note in passing that fine sawdust played an important part in their production, the helmets, after being first painted, receiving, while the paint was wet, a coat of sawdust from a blower, after which the dried and roughened surface received a second coat of paint. The purpose of this treatment was, of course, to break up and dissipate reflected light.

Perhaps the most striking offensive development of the war was the employment of toxic gases and latterly of toxic smokes. These gases were of many sorts, but chlorine was the one first used by the Germans in their attack in the Ypres salient in April, 1915, and this was so disastrous in its effect that had it been followed up, the Germans could undoubtedly have gone through to the coast with practically no opposition. The Germans in their earlier attacks discharged the gas from great numbers of cylinders placed within the trenches, and the direction and velocity of the wind determined the possibility of a gas attack. Both the Germans and the Allies, therefore, quickly resorted to the use of gas in shells, while the Allies developed the extremely effective Livens projector, which, firing simultaneously sometimes to the number of hundreds, discharged upon a localized area gas-filled drums about 24 inches long and 8 inches in diameter. Their effective range was about a mile. Much gas was also thrown in hand grenades.

Field experience and the conditions imposed by quantity production soon narrowed the number of available gases to relatively few, and of these phosgene was one of the most toxic. Certain thermochemical considerations led to an ingenious modification of the method of production, and phosgene was produced in great amounts by passing a mixture of oxygen and carbon dioxide over hot coke in gas producers and thereafter sending the carbon monoxide thus formed through catalyzers, together with chlorine, which, combining with the carbon monoxide, produced phosgene.

The chief seat of poison-gas manufacture in this country, though its production was largely supplemented elsewhere, was Edgewood Arsenal, which, producing its chlorine by the electrolysis of a solution of common salt, had a phosgene capacity of 20 tons a day.

Chloropicrin also played an important part in gas warfare and was produced at Edgewood to the amount of 2,320,000 pounds, the maximum amount actually produced in one day reaching 31 tons. It is made by treating calcium picrate with bleaching powder and steam and thus involves as ultimate raw materials limestone for making lime, benzol produced from coal in by-product coke ovens, and nitric and sulphuric acids for effecting the conversion of benzol to picric acid. Coal is again, of course, involved in the production of steam, and for the bleaching powder we have to turn once more to limestone for the lime and to chlorine resulting from the electrolysis of salt.

Perhaps the most generally effective of all the substances used in gas warfare was dichloroethylsulphide, or mustard gas, produced by blowing gaseous ethylene into liquid sulphur monochloride. Ethylene is a product of the destructive distillation of coal in gas works, but in this case was made by passing alcohol over hot kaolin. Sulphur is, of course, a basic resource, and, again, the chlorine comes through the electrolytic decomposition of common salt.

At the date of the armistice Edgewood was making 30 tons a day of mustard gas and other great plants were building—all to a total daily capacity of 200 tons. The military importance of the material may be judged by the fact that at one time proposals were under discussion for an output of 1,400 tons a day.

Since the Germans introduced mustard gas, it is pleasant to be able to say that we ultimately greatly outdistanced them not only in the efficiency of the process itself, but in the amount and rate of production, which last was finally ten times that of Germany.

As the wearing of a gas mask, particularly of the earlier types, greatly reduced the efficiency of troops and tended to lower their morale, substances which forced the wearing of the mask proved highly effective. They were known as tear gases and involved bromine as an essential constituent. Our domestic source of bromine is certain subterranean brines, especially those about Midland, Mich., and a bromine plant was built with an annual capacity of 650,000 pounds of this element.

The tear gas adopted by us was brombenzyl cyanide, and a single shell thus loaded could force the wearing of masks over an area so extensive that from 500 to 1,000 phosgene shells would be required for the same effect. The compound itself was made by chlorinating toluol, thereby forming benzyl chloride, which was mixed with sodium cyanide in alcoholic solution and distilled with the production of benzyl cyanide. Finally, this was treated with bromine vapor. Thus the production of this single compound involves the electrolysis of salt to obtain chlorine, the distillation of coal for toluol, the bringing

together of soda, iron, and nitrogen to react for the formation of sodium cyanide, the distillation of grain or molasses or sugars derived sodium cyanide, the fermentation and distillation of grain or molasses or sugars derived from wood waste for alcohol, and the extraction of bromine from deep-well brines.

We shipped to Europe in bulk of all these gases 3,662 tons, together with 18,600 Livens drums loaded with phosgene. Edgewood was, moreover, a filling station with a filling capacity of nearly 1,000 tons of gas a week or one million two hundred thousand 75-millimeter shells per month for the time being, with extensions under way to double that output. The Edgewood production of filled shells was, however, greatly restricted by the failure in deliveries of shells and boosters, only 300,000 of the former and 200,000 of the latter being available monthly.

The demand for pyrotechnics, including signal rockets, parachute star rockets, flares, smoke torches, and 20 styles of star shells to the number of several million in all, strained the producing capacity of the country to the utmost and involved the production in large amounts of many special materials. Phosphorus, for example, was largely used in smoke shell, as was also stannic chloride in the smoke funnels of the navy. Magnesium was required in great amount for wing tip flares for the night landing of airplanes and for ground flares. The airplane flare for night bombing carried 32 pounds of magnesium, was suspended by a silk parachute, and burned for 10 minutes with a power of 320,000 candles.

The development of the airplane greatly extended the demand for military supplies, the chief materials entering into their construction being wood, sheet steel, wire, cloth, dope, and varnish. For the frames certain qualities of spruce are preferred, although some species of fir are also used. We took in all 180,000,000 feet of aircraft lumber out of our northwestern forests, of which two-thirds went to the Allies, while one-third was used by us. The average plane utilizes less than 500 feet from 1,000 feet of rough lumber, but in the earlier production as much as 5,000 feet of rough lumber per plane was consumed. In exchange for finished planes, we supplied the French with raw materials and parts, sending them about 35,000,000 feet of spruce, fir, and cedar, 7,000,000 of mahogany or enough for 40,000 propellers, 4,000 tons of aluminum, much dope for the wings, ball bearings, steel, brass, copper, and aluminum tubing, together with sheet metal of various sorts.

The average plane requires 250 yards of fabric, and some of the larger over 500 yards, in addition to that needed for spare wings. Linen was the cloth first used, but with the cutting off of supplies from Russia and the Courtrai district in Belgium, the stock was soon

inadequate. A better cloth was thereupon developed in this country from long staple mercerized cotton, and over 10,000,000 yards were woven and delivered.

At the time of the armistice the United States had contracted for more than 100,000 aircraft engines, of which over 64,000 were Liberty engines, for which Ford was turning out 2,000 rough cylinders a day.

At one time the entire airplane program was jeopardized by the limitations of the supply of acetate of lime, the source not only of acetic anhydride essential to the production of the cellulose acetate used for airplane dopes, but also of acetone required by the British as a solvent in the manufacture of cordite. In this situation Arthur D. Little, Inc., had the satisfaction of developing in its laboratories two alternative dopes which made no demand upon the acetate of lime supply. One had for its base cellulose butyrate, the acid for which was derived from Pacific Coast kelps. The other used a solution of zein, a protein existing in the germ of Indian corn. In all more than 1,300,000 gallons of airplane dopes were made in the United States.

At the date of the armistice we had produced 11,754 planes and were making over 10,000,000 rounds of aircraft ammunition per month.

Besides the high explosive bombs used in aero warfare, interest attaches to other types, among which may be mentioned the incendiary bombs and the dummy bombs for target practice. The former weighed 40 pounds each and were loaded with an oil-emulsion-thermit mixture and metallic sodium, the latter to nullify efforts to put out the fire by the use of water. Over 122,000 incendiary bombs were ordered, and 86,000 were received. The demand for dummy bombs was even greater. These were made of terra cotta at a cost of about \$1 each. They carried a small charge of phosphorus and a loaded paper shot-gun shell. On contact they emitted a puff of smoke to advise the aviator of the accuracy of his aim.

Before leaving aviation supplies mention may well be made of the alloy resistance wire woven into the aviator's clothing to supply warmth on the passage of an electric current.

The war vastly extended and developed the old art of camouflage, and its practice made great demands upon burlap from India, which was used by the British and ourselves, and upon raffia from Madagascar, which the French employed. Both materials were employed in strips, woven into fish net and wire netting, and colored with an oil emulsion paint. Some types of battery positions required 4,000 square yards of camouflage cover, and hangars and hospitals took great amounts. All told, we required for these purposes alone about 3,000,000 square yards of burlap a month.

Out of the great multitude of miscellaneous supplies a few may be selected as especially significant. We shipped abroad 21,000 tons of steel barbed wire. The Germans used in barbed wire a manganese steel which our first cutters could not sever. They had, therefore, to be redesigned. We used over 200,000 marching compasses and ordered $1\frac{1}{4}$ million trench knives with cast-bronze handles. Files were required by tens of millions, and more than 500,000,000 pieces of small hardware. A million currycombs, 1,200,000 axes, 76,000 lariats, and nearly as many 5-foot steel measuring tapes were minor items of supply, as were a quarter million storage batteries for radio work and $7\frac{1}{2}$ million feet of moving-picture film. The balloon program called for 20,000,000 yards of highly specialized cloth, which required the construction of thousands of looms and therefore increased the demand for steel. In four days of the final drive of our troops in the Argonne district, the photograph sections of the air service made and delivered 100,000 prints from negatives taken above the battle lines. Such service involved the problems of optical glass and all the details of photograph equipment. On November 11, 1918, there were in France 282 American telephone exchanges, 9,000 stations, about 15,000 telephone lines, and in all, 96,000 miles of newly constructed long distance telephone and telegraph lines. The Signal Corps requirements for outpost wire were rising to 68,000 miles a month, and we were producing 40,000 miles. This was a twist of two strands, each composed of four bronze wires and three of hard carbon steel. They were stranded together, coated first with rubber, then with cotton yarn, and finally, with paraffin.

The brief and necessarily meager reference which has been made to a few of the more important or spectacular items of military supply in the war just closed has had no other object than that of calling attention for the moment to the extraordinary range and volume of the demands made upon the resources and productive capacity of a country by military necessities. Our entry into war was not unlike the passage from one type of civilization to another. We had to accomplish in a few months a change as profound as that with which Japan was confronted in 1854 when Perry's ships cast anchor in the Bay of Tokyo. This new civilization was wholly alien to the old in its social conditions and in its demands upon the products of industry. It quickly taught us that troops can be organized and trained far more quickly than industry can be revolutionized to supply their needs. And, as the Assistant Secretary of War, Mr. Benedict Crowell, from whose report much of these data have been taken, says in his introduction thereto, "The experience of 1917 and 1918 was a lesson in the time it takes to determine types, create designs, provide facilities, and establish manufacture."

One may add that it has also taught that no country is wholly self-contained as regards the materials essential to successful military operations. It must keep the seas open for the transport of supplies from other countries, as, conspicuously in our own case, rubber, tin, manganese, graphite, platinum, wool, and knitting needles.

It is in this connection instructive to consider briefly the position of Germany as to natural resources at the beginning of the war and the part which natural resources played in respect of Germany's incentives, aids, and inhibitions. These and other interesting relationships are admirably presented in *The Strategy of Minerals*, prepared by members of the Geological Survey, to whom I am indebted for the statistics which follow concerning mineral supplies.

The greatest body of iron ore in Europe was shared by France, Germany, and Luxemburg. France was most favorably placed as to actual reserves, but Germany had the advantage in mining costs. France has no adequate supply of coking coal, while Germany has a great supply of the best coal of this type in Europe. Even now that the Lorraine ores and the Saar Basin coal have passed under French control the position of Germany is not irreparably bad since ore commonly and naturally goes to coal.

These minette iron ores of eastern France were coveted by Germany, and had Germany in 1871 held Belfort and Verdun she would have had in her possession the whole iron-ore reserves of the Moselle Basin, and such possession would at least have removed a great incentive to war and might well have made her invincible had she gone to war.

In 1913 Germany produced a little more iron than France, Belgium, and the United Kingdom together. All four countries produced 48 per cent of the world's output, to which the United States contributed 40 per cent in 1913, and in 1916 a little over 50 per cent. In 1913 three-fourths of the German ore mined in Germany proper came from annexed Lorraine, and four-fifths of all the ore produced within the German *Zollverein* came from Lorraine and Luxemburg.

At the onset of the war Germany obviously aimed to cripple France by crippling the French iron industry, and her early control of the coal and iron of Belgium and northern France proved of the utmost advantage to her and did much to prolong the war.

Nine-tenths of the iron ores mined in France came from the closely contiguous districts of Longwy, Briey, and Nancy. Germany, therefore, at once invaded the Briey district and the Longwy district immediately thereafter. As a consequence, Germany in September, 1914, held respectively, 68, 83, 80, and 75 per cent of France's capacity for producing coal, iron ores, pig iron, and steel and was in complete control of the coal-mining and iron-making industries of Belgium.

Had Germany won and held the minette ores of eastern France she would now be in possession of 45 per cent of the iron-ore reserves of Europe and could have supplied 77 per cent of her requirements from her own ores, as contrasted with 56 per cent before the war. There has never been a balance between German iron ores and coal, the excess being largely on the side of coal. She had, however, access to the rich iron ores of Sweden and through her alliance with Turkey to the chrome ores of Asia Minor. As A. C. Spencer, of the Geological Survey, says: "Truly iron entered largely into the underlying strategy of Germany's attempted conquests: First, providing a reliable industrial basis for war; second, offering a means of quickly disabling France; and third, proffering a grand prize in the minette ores of Muerthe-et-Moselle, which if attained would insure industrial supremacy against all rivals."

Among mineral resources Germany's monopoly was potash, and even this is now likely to be broken with the passing to France of the great deposits of Alsace and the stimulus given to potash production in this country by the war. Even more significant is the fact that, except for coal, cement, and possibly zinc, Germany has always been forced to import mineral supplies to supplement the deficiencies of her own production or reserves. As to essential war minerals, like tungsten, manganese, copper, nickel, tin, platinum, chromite, sulphur, and petroleum, German resources were either wholly inadequate or totally lacking. As a necessary preliminary to any serious war Germany had therefore to build up through importation great stores of these war minerals, and it is highly significant to note that German importations of nickel, manganese, brass, sulphur, and tin showed large increases during the immediate prewar period. For example, the average increase in the general trade of Germany with the United States was only about 7 per cent a year, whereas shortly before the war German demands upon us for war minerals and metals jumped suddenly in some cases several hundred per cent.

Moreover, a few years ago, Germany, like all the rest of the world outside of Scandinavia, was dependent upon Chile for sodium nitrate as a source of the nitric acid which puts the energy into explosives. In view of this dependence, and through fear of diminishing supplies, the attention and effort of chemists were directed to the atmosphere as a source of nitrogen through fixation of this component as ammonia, nitrate of lime, or otherwise.

Up to about 1910 or 1911 there was practically no fixation of nitrogen outside of plants in Norway and Sweden, but about 1912 Germany, which had been experimenting with the arc process, had one quite large Haber plant in process of construction. In 1915

two large Government cyanamid plants were started, though these were not completed until well into 1916. According to figures contained in the final report of the nitrogen products committee of the English Government, which was issued in January, 1920, Germany had a producing capacity in 1915, which carried through into 1916, of 500,000 metric tons of cyanamid, which is roughly equivalent to 90,000 tons of nitrogen. When one realizes the importance of nitrogen and its derivatives in military operations, one can see to what purpose Germany's early experiments in its production were directed.

Germany did possess a highly developed by-product coke and dyestuff industry, with all its collateral advantages in the manufacture of high explosives from benzol, toluol, etc., and she had a vast and highly organized and elastic industry, which is at least as essential to military success as the natural resources and raw materials of a nation.

Having thus in mind a few of the more salient features in the situation of our chief antagonist as to ultimate supplies, and keeping still before us the compelling and inclusive demands of military necessity, let us consider briefly the more direct relationships of these demands to specific natural resources.

Coal puts the bone in the teeth of battleships, and though petroleum may for a time make the bone look larger we shall ultimately—and it may be soon—return to coal for driving power. Its energy turns the propellers of steamships, transports, cargo carriers, and the countless other vessels whose sailing orders are determined by the needs of war. It hauls foodstuffs, munitions, and raw materials. It smelts ores, converts hematite and limonite to steel. It furnishes light and heat and power. Through its distillation coal supplies benzol, toluol, ammonia, and phenol for explosives; coke for carbide; acetylene and carborundum; graphite for electrodes and for lubricants; and coal tar for dyes. The distillation of a ton of average coal yields 1,500 pounds of coke, 10,000 cubic feet of gas, 22 pounds of sulphate of ammonia, more than 2 gallons of benzol, and 9 gallons of tar. Under the stimulus of war the output of our by-product coke ovens was increased to more than one-half the total coke output in 1918. Such increase was highly important since it forms the basis for the coal-tar industries, including dyestuffs, high explosives, and synthetic drugs, as salvarsan.

Germany has more coal than other European countries, but only one-eighth as much as the United States, which has 21 times as much as Great Britain. Moreover, the output of British coal was for a time jeopardized by the lack of mine timbers from the Baltic ports. France has always depended largely upon Germany for coal and must

still so depend, although her control of the Saar Basin gives France about 18,000,000 tons of coal a year.

Since coal is a basic raw material, without which no modern war could be fought at all, it is gratifying to realize that not only is the United States the greatest coal producer in the world, but that we also have the world's greatest reserves of iron ore within the North Atlantic Basin, where our coal reserves are largely located. Ninety-six per cent of the world's reserves of coal are in the northern hemisphere; about 70 per cent are in North America, and over 50 per cent in our own country. Our production of soft coal in 1918 was over 585,000,000 tons, an increase of 38 per cent over the output in 1914.

Industrial preeminence and therefore military power rest on coal and iron. Together, these constitute 90 per cent of the world's mineral output. Of all belligerent countries the United States is the only one with well-balanced coal and iron reserves. Ore goes to the coal, and the coal locations, therefore, determine those of industrial developments and markets and consequently those of iron furnaces.

Speaking generally, the limiting factor in coal production is the number of empty cars which the railroads can place at the mines, and our own coal troubles during the war were really due to the congestion of our railroads due to other freight. A similar congestion of transportation was experienced in all the belligerent countries and emphasizes the need of avoiding coal transportation wherever possible. This has led to proposals for superpower plants at the mines in England and to great plans for common-carrier transmission lines for power in the industrial region along our own North Atlantic coast.

Before the war it was a common practice to haul the coal from one field over other coal fields and past the mouths of operating mines much nearer the ultimate destination of the coal so transferred. The zoning system which we adopted put an end to much of this needless transportation and led consumption to the territory nearest the producing field. Moreover, in a time of war a consumer's right to any commodity must be conditioned by the relation of his activities to the national necessity, and the early recognition of this limitation led to the establishment of priority schedules covering coal and other essential raw materials.

The railroads of the United States use 27 per cent of the coal we mine, and they use much of it in transporting coal itself. To save transportation, therefore, a system of rigid inspection was instituted, for with crippled transportation facilities we could not afford to haul slate and bone and dirt.

Nowhere in the world does there exist another general storehouse of useful minerals comparable to the United States, but natural

resources in themselves have only potential values, which require for their realization industrial skill, technical knowledge, great reserves of capital, and efficient transportation. We have been able to demonstrate that, with the exception of the last, we are in position to bring effectively to bear all these factors so essential to quantity production. Even as regards transportation we are, so far as the steel industry is concerned, most fortunately situated; so fortunately, indeed, that the Great Lakes waterway, which permits a transportation rate of less than 0.7 mill per ton-mile, may properly be regarded as the determining factor in our position as the world's greatest producer of iron and steel. In the decade ending in 1913 we produced 248,000,000 metric tons of pig iron. The German output was 140,000,000, and the combined production of the United Kingdom, France, and Belgium 154,000,000. Under the stress of war our blast and steel furnaces increased their output by 30 to 40 per cent respectively between 1913 and 1919, thereby justifying the conclusion that the United States must now possess one-half the steel-making capacity of the world. During the same period the British output increased 27 per cent.

We have already had in the methods of fixing atmospheric nitrogen an interesting example of the extent to which both the absolute and relative military position of a country may be modified by a new chemical process. An equally striking example is found in the metallurgy of steel. The original Bessemer process, using an acid lining in the converter, required for its effective operation pig iron with an extremely low phosphorus content. Thomas and Gilchrist introduced the basic converter process by lining the crucible with calcined dolomite and adding lime to the charge, dolomite itself being a mixed carbonate of lime and magnesia. They were thus enabled to operate on iron containing 2 per cent or even more of phosphorus, thereby making available the great reserves of ore in Sweden, Russia, Central Europe, and Lorraine, and so introduced new and disturbing factors in the industrial, military, and diplomatic situations in many countries.

The supreme importance to modern civilization of alloy steels in naval construction, ordnance, metal working, automobiles, and countless other directions is too well known to require comment. The metals commonly used in these alloys are manganese, chromium, molybdenum, nickel, tungsten, vanadium, and latterly zirconium, which finds its chief use in steel for armor plate and armor-piercing projectiles. Its ores come from Brazil, but the metal may be obtained from the zircon sands of the South and from western mine tailings. The United States is well supplied with most of these essential metals, though there is a deficiency in ores of manganese and

chromium, our domestic ores being of such relatively low grade that their use would involve important changes in practice. Practically all of our manganese, or 99 per cent, was, before the war, imported by our steel makers from south Russia, then from India, and finally from Brazil, but during the war we so greatly increased our domestic production as to become for the time being nearly independent. We were most fortunate in this regard, for in modern steel making manganese has become almost as necessary as iron itself.

Chromium is another of the most essential war minerals, although this is by no means monopolized in steel making. Its use has revolutionized the tanning industry, and its compounds are much used in dyeing, particularly in the khaki shades. We have always produced a little chromite here, but the world's center of production was Turkey and later Rhodesia and New Caledonia. Before the war we obtained our chromite chiefly from Rhodesia and New Caledonia. It now comes from Brazil, Cuba, and California, but our own deposits will soon be exhausted if worked at the war rate.

Nickel is perhaps the most widely used alloy component of steel, its presence conferring such hardness and elasticity that nickel steel is used for steamship shafts, armor plate, shells, structural steel, and rails. The world depends for its supply upon Canada, whose reserves are estimated to contain 150,000,000 tons of ore, an amount apparently sufficient to meet the requirements for another century.

Modern metal working, with all that it involves in the use of tools and the construction of machines, may be said to rest on tungsten because of the greatly increased efficiency of cutting tools of tungsten steel, due to the fact that tungsten raises the temperature at which steel holds its temper. Tungsten ores are rare and widely scattered, the United States, Burma, Indo-China, Bolivia, and Portugal being the principal producers. The world's output is only about 25,000 tons of tungsten ores figured on the basis of 60 per cent of tungstic oxide. These are smelted in electric furnaces for metallic tungsten or alloys like ferrotungsten. Tungsten has a further and important, although indirect, influence upon the efficiency of production through its use in mazda lamps, in which the tungsten filament functions so efficiently as to produce far more light with the same expenditure of current. It is interesting to note that not only did Germany hoard tungsten before the war, but that the submarine *Deutschland* carried 55,000 pounds of the metal from the United States.

The universality of the use of copper both in war and peace needs no comment, and the greatly increased demand for the metal, due to the expanding demands of the electrical industries, is manifest. The proportion of such use to that of iron has steadily increased from the ratio of 1 to 104 in the period from 1880 to 1885 to 1 to 53 in

1916. The demand for copper by the Central Powers caused roofs to be stripped and brass and bronze articles of use or ornament to be everywhere commandeered. Our own position in regard to copper may be summed up in the statement that the Americas yield 75 per cent of the world's output and the United States almost 60 per cent.

We have in the flotation process as applied to copper production another good example of a new industrial method, due to research, which in the nick of time permitted a vast expansion in the output of an essential metal.

Zinc, which finds a great use in brass, composed normally of two-thirds copper and one-third zinc, enters obviously into the constitution of a vast variety of military supplies. The demand for zinc led to an orgy of zinc smelting because most of the world's smelters outside of Germany and the United States stood along the Meuse River in direct line of the German advance. As to this metal Germany was favorably placed, since one of the greatest zinc fields in the world is in Silesia. The Allies, however, suffered immense losses of brass during their retreat early in 1918, and toward the end of the war the United States became practically their sole source of supply. The shortage of copper in Germany led in that country to the substitution therefor of various alloys of zinc.

Lead is one of our most useful metals and has been identified with military operations since the arquebus replaced the crossbow. It is almost indispensable for pipe, solder, bearing metals, terne-plate, small arms, bullets, shrapnel, and functions with perhaps equal effectiveness in the type so essential to propaganda. The United States has always imported much lead ore from Mexico. The supply was short in 1917, but increasingly stable conditions in that country enabled her to send us almost as much lead in the first half of 1918 as we imported from all countries in the previous year.

For many uses antimony is closely associated with lead by reason of the greatly increased hardness of antimony-lead alloys. Antimony, therefore, also finds extensive use in the type foundry and is a common constituent of bearing metals.

Reference has already been made to the ubiquity of the indispensable tin can, and the shortage of tin was the cause of almost as much anxiety as that of platinum, the world's output of 140,000 tons being inadequate to meet the demand. We ordinarily consume 70 per cent of the world's supply, to which we contribute practically nothing. Tin finds important use as a constituent of solders, in which, however, it may, if necessary, be replaced by cadmium, and some cadmium was used in France as a deoxidizer in bronze for telephone and telegraph equipment.

Aluminum is one of the most important and interesting of all the war metals, and its whole history is replete with peculiar interest.

For its production cheap water power is essential, and the raw materials involved are bauxite, which we obtain from our Southern States or from France, and cryolite, a double fluoride of aluminum and sodium, for which the world is dependent upon Greenland. In 1883 the United States produced only 80 pounds of aluminum, whereas our output in 1914 was 80,000,000 pounds. Our producing capacity at this time is greater than that of all other nations combined. Aluminum is of vast importance in the construction of airplanes and dirigible balloons, since it is the lightest metal available. It constitutes the framework of dirigibles and enters largely into the construction of their engines and that of automobile parts and engines. It is an essential constituent of the explosive ammonal and of thermit in its many applications as a constructive and destructive agent. Aluminum has, moreover, great potentialities and some present use as a substitute for copper in the transmission of electricity.

The Lewis ground gun has an aluminum heat radiator surrounding the barrel, and the shortage of aluminum actually held up for a short time the manufacture of gas masks by reason of the difficulty of securing pure aluminum sheet for the eyeglass rims, practically all the metal having been absorbed in the making of aluminum die castings for shell and other ordnance. For the same reason hundreds of valuable brain hours were spent in the development of hard-rubber die castings and complicated brass stampings merely to save the little bit of aluminum required for gas-mask mouthpieces. Troubles of this kind could be largely eliminated by the military man if in his peace-time studies of design he would allow the necessary large factor of safety between war-time supplies and demand. This is especially true, for example, in the case of design of ordnance, such as shell, for if the nose of a shrapnel fuse is made in peace time of an aluminum die casting, it is too late when war comes to substitute anything else, for the change would affect the entire ballistics of the shell and its ranging.

The mineral magnesite, which is a carbonate of magnesium and essential to the steel industry by reason of its use for furnace linings, was imported previous to the war, but altogether adequate supplies are now received from great deposits located in Washington. The metal magnesium itself is much lighter and stronger than aluminum, but, unfortunately, is very susceptible to corrosion by oxidation. Although useful, therefore, in some alloys, as in those with aluminum, its chief war value is for flares and pyrotechnics, to which reference has already been made. Production in the United States began in 1915 and in 1917 had reached 116,000 pounds and was increasing very rapidly. The electric furnace production of the metal from magnesium chloride requires cheap water power and coal.

With a possible exception of steel, no metal is more vitally essential to the conduct of modern warfare than platinum, though there is probably not more than 10,000,000 ounces—approximately 425 tons—in use in the world to-day, and of this probably 95 per cent came from Russia. The importance of platinum is chiefly due to its extensive use as a catalyst in the synthetic production of such fundamentally basic supplies as sulphuric acid and ammonia, and it functions similarly in the manufacture of many other compounds. It is indispensable for certain chemical equipment, and a light film of platinum on glass is an essential part of Navy range finders.

The importance of mercury as a war metal is altogether disproportionate to the small amount used. It finds employment in periscope mirrors, thermostats, clinical and technical thermometers, and as mercury fulminate in priming charges. Corrosive sublimate, which is vitally important in surgery, is mercuric chloride, and the red oxide of mercury finds effective use in paints for ships' bottoms. We depend chiefly upon California for our mercury, and the Central Powers drew upon Austria and possibly Asiatic Turkey for their supply.

Graphite crucibles are essential to the industries employing non-ferrous metals, and for such crucibles we have heretofore depended upon the flake graphite coming from Ceylon, our own supplies of graphite being of the amorphous variety. Under the stress of necessity, however, entirely satisfactory mixtures composed in large part of domestic graphite were developed.

The whole structure of modern chemical industry, with all the ramifications arising from military demands, is based upon sulphuric acid, made either from pyrites or from native sulphur. Of the latter our immense deposits in Louisiana and Texas made it possible to increase our 1913 production of $3\frac{1}{2}$ million tons of 50° acid and 23,000 tons of acid above 66° to 6,000,000 tons of 50° acid in 1917 with 760,000 tons of the stronger acid, which finds its chief use in the production of explosives. Sulphuric acid is also largely used in the refining of petroleum and the pickling of metals.

Portland cement, made from limestone and clay or clay-bearing limestone, is obviously a military supply of the first importance, entering into foundations and construction of all sorts—roads, dugouts, "pill boxes," and even ships, well named *Faith*. Fortunately, both our producing capacity and our supply of raw materials proved adequate to all demands.

Similarly, it may be pointed out that crushed stone for road construction proved so vitally important to military operations that it is said that in France, next to the transportation of troops and ammunition, the transportation of crushed stone had priority over practically everything else.

In spite of the vast and even overshadowing importance of petroleum and its products as war supplies, space permits only an incidental reference thereto. The United States leads the world in petroleum production and provides about two-thirds of the world's supply. Fuel oil has revolutionized naval design and tactics, and during the fiscal year of 1919 the Navy used 10,500,000 barrels. Practically every piece of operating machinery in the world depends for its proper functioning upon the lubrication of its moving parts by petroleum products. Automotive transportation and the flight of airplanes depend for the present at least on gasoline. We have reached the peak of our petroleum production, and consumption has overtaken the supply. Fortunately, we have another source of gasoline in natural gas, from which we secured in 1913, 24,000,000 gallons and in the first half of 1918, 175,000,000 gallons. Here, again, we have, however, no promise of a continuing supply.

The effective use of the airship and the observation balloon as instruments of war is greatly curtailed by reason of the dangers due to the extreme inflammability of the hydrogen upon which their lifting power depends and the explosive character of mixtures of hydrogen and air. When a balloon was hit by an incendiary bullet the interval between the initial burst of flame and the final explosion was rarely more than 15 to 20 seconds. The average life of a kite balloon on an active sector of the Western front was 15 days, while some lasted only a few minutes. It became obvious, therefore, early in the war that if it were possible to substitute for hydrogen a non-inflammable gas of substantially the same lifting power the military value of both balloons and airships would be greatly augmented. Such a gas—helium—was known to exist in the atmosphere in the proportion of 1 volume in 250,000 volumes of air. Its existence in proportions reaching $2\frac{1}{2}$ per cent by volume had been demonstrated in the natural gas from certain wells in Kansas, Texas, and elsewhere, but prior to 1916 the total world production had not reached 100 cubic feet at a cost of \$1,700 or more per cubic foot. On armistice day we had on the docks 147,000 cubic feet and were building plants for the extraction of 50,000 cubic feet a day. Thus through the declaration of war has a natural resource, so rare as to constitute a chemical curiosity, suddenly been established as a military necessity of the first order. Helium can not be ignited or exploded; its diffusion rate through balloon fabrics is about two-thirds that of hydrogen; it has over 92 per cent of the lifting power of hydrogen; it permits with comparative ease the passage of electric discharges, and had it been available in quantity would have placed the entire aeronautical program on a vastly more effective basis.

Nothing perhaps could better illustrate than helium the changing relation which specific natural resources may bear to military supplies. The usefulness and value of any natural resource for military as for industrial purposes will always be conditioned primarily on our own ability to employ them to advantage. Such values are not intrinsic, but are established by research, and their basis is scientific and technical knowledge. The effective encouragement of science is the price of military efficiency.

GLASS AND SOME OF ITS PROBLEMS.¹

By SIR HERBERT JACKSON, K. B. E., F. R. S.

Before I begin the lecture, I should like to say how much I appreciate the privilege of being asked to give this, the second Trueman Wood lecture. Our chairman has stated the origin of these lectures, namely, to keep alive the memory of the long and distinguished work of Sir Henry Trueman Wood in promoting and increasing our knowledge of the arts and sciences in the best interests alike of this Society and of the Nation. I am sure I express the feelings of everybody present when I say how delighted we are that he is here to-day and when I express the hope that he may be able to attend many more lectures to be given in his honor.

It was suggested to me that this lecture should have something to do with glass, and it was hoped that there might be experiments. The production of glass is difficult to illustrate efficiently in the course of a lecture. It will, therefore, only be dealt with very briefly and generally before turning to some of the problems connected with glass which I hope to make the chief part of this lecture. The chairman, in his opening remarks, has spoken of the many varieties of glass. We hear of optical glass, window glass, table glass, industrial and scientific glass, opal glass, colored glass, etc., all of which have many properties in common while exhibiting differences which depend chiefly upon the materials used in making them, the various proportions in which the materials are used and, to some extent also, on the methods of manufacture. It will be convenient to take window glass as one of the simplest of glasses, and briefly to consider its composition. The essential materials required are sand, chalk, and sodium carbonate. When these are heated together in suitable proportions, there results a glass containing silica, or the oxide of the nonmetal silicon; lime, or the oxide of the metal calcium; and soda, or the oxide of the metal sodium, combined together to form what is generally spoken of as a soda lime silicate. Of these ingredients the silica is the acid constituent, and the lime and soda are the basic constituents of the glass. Most glasses are composed of acids as oxides of nonmetals, and bases as oxides of metals combined together. The chief acid ingredients to be found in various

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glasses are silica, boron trioxide, arsenic trioxide, and pentoxide, phosphorus pentoxide, tin oxide, and antimony pentoxide. The chief bases are the oxides of potassium, sodium, lithium, barium, calcium, magnesium, zinc, and lead. Aluminium oxide, a constituent of several glasses may, in some, play an acid part and in others may act as a base. With certain reservations, this may be said also of antimony trioxide. The list is not exhaustive, but is sufficient to indicate that a number of glasses is possible from various combinations of these acids and bases. (The materials used for producing opals and colored glasses will be referred to later.) The number of glasses made is very large, and it would take at least all the time at my disposal to describe in any adequate manner how they differ from one another in composition and in those properties which make each one suitable for the purpose for which it was devised. It may, however, be appropriate here to mention that in the great variety of optical glasses, there are many which do not differ materially in composition from glasses used for other purposes. For example, a good window glass could be made with pure materials and stirred in the process of its manufacture, so as to secure such a clear and homogeneous product as would serve as one type of optical glass. The chief general properties which are desirable in all optical glasses are identity of composition throughout the whole mass of the glass, great clearness and transparency for all the colors of the spectrum, freedom from strain arising through imperfect annealing, and durability under ordinary exposure to the atmosphere. It will be seen, therefore, that apart from considerations of special optical properties, I refer to the refractive indices and dispersive powers of various optical glasses; the main difference between them and other glasses is that the highest art of the glass manufacture is called for in their production, and great care is needed to insure purity of the materials used and accuracy of proportions, so as not only to be able to produce glass of the optical properties required, but to reproduce it with the closest possible identity of composition. With these very brief remarks on glass generally, we may turn now to some of the problems which I thought might be interesting to consider, and the first one is how far can glass be called a solid?

A solid is defined in a dictionary as having a fixed form and being in a state in which the component parts do not tend to move freely among themselves. With regard to glass, we may ask for how long is it fixed in form, and what are the limitations of freedom of movement which we ought to consider? It is a common experience that long straight pieces of glass rod or tubing, left supported so that their own weight tends to bend them, will bend in the course of time, and in some years will become definitely bowed. Varieties of glasses

differ in the readiness with which they show this flow under stress; but not any glass is so perfectly solid as to give no indication of movement under stress if tested by sufficiently delicate means. This question of permanent stability of form in glasses has some bearing on the choice of glass for the manufacture of large lenses and prisms, and the flowing of the surface of glass under mechanical pressure comes in as a very important matter in the explanation of the mechanism of polishing glass surfaces. A great deal has already been written on this subject, and it would take too long to deal with it here. Another reason why I refer to it but intend to leave it is that I hope it will not be long before the published papers and other work of Sir George Beilby on the influence of mechanical disturbance on the physical state of a very large number of substances will be brought together into one connected story, when it will be seen that this subject of polishing glass has been dealt with in a comprehensive manner, and that the principles underlying it are shown to have very wide application.

The question of the relative plasticity of various glasses has two important bearings which are of some interest. For many industrial and scientific purposes it is necessary to be able to seal metallic wires into glass, and early in the war some difficulties were experienced in obtaining suitable glasses. To obtain successful joints between the metal and glass without fear of the latter cracking, it was generally considered that the glass aimed at should be one which had a coefficient of expansion as close as possible to that of the metal intended to be used, and there is no doubt that this question of expansion has to be taken into account. In making a large number of glasses and in experimenting with them there did not appear to be that close connection between the coefficient of expansion of the glass and its behavior with metal wires which was at first expected. The coefficient of expansion of copper is about double that of platinum, and the coefficient of iron is about midway between the two. Glasses were made which gave successful joints with platinum and copper wires, but which cracked inevitably with iron wire. It did not appear, therefore, that the coefficient of expansion was the only factor to be taken into consideration. It is an important factor, but not the only one, and it soon became clear from the study of various glasses that the plasticity of the glass had a great deal to do with its utility. A careful examination showed that there was evidence that in the case of soft metals, like copper and platinum, the glass in setting could pull and deform the metal wires so that no great strain was permanently left in the glass. With hard metals like iron and tungsten, it was necessary to devise a glass which had marked plasticity over such a long range of temperature that when

the glass and metal joint cooled, the glass would flow and follow the contraction of the metal and so the stress would, to some extent, be relieved. And this is an example of the need of asking the question: Is glass truly a solid, and how far can a glass be made which will flow, very much less, of course, than pitch, but in an analogous manner? The other bearing of the question is on the cracking of glass vessels with rapid changes of temperature. It is clear that if the strain set up by such changes can be quickly and readily released, the danger of cracking will be very small. The coefficient of expansion is, of course, a very important factor in this respect. It is well known that vitreous silica vessels can be heated to redness and plunged into cold water without cracking, and this is, no doubt, correctly considered to be due almost entirely to the low coefficient of expansion of silica. In the case of glasses also, the lower the coefficient of expansion of a glass the better will that glass stand rapid changes of temperature; but it is possible to make glasses approximately with the same coefficient of expansion and to find one—and that, perhaps, the one with a slightly higher coefficient of expansion—which will not crack under conditions in which the other cracks readily, and a study of the two glasses shows that the more stable one is the more plastic. On the whole, perhaps, it is not too much to say that glass may be looked upon as an extremely viscous liquid so slow in its movements in some types of glass that ages might elapse before any marked change in form could be observed under a strain just short of a breaking one for the glass, while in others it is possible to show that the glass does flow, even at the ordinary temperature, to a small extent in a relatively short time.

The next problem to be considered may be also put in the form of the question: Is glass truly amorphous or vitreous or has it any crystalline structure or tendency to crystalline structure? There are many substances which can be obtained in the vitreous state and also in the crystalline state, and which can be changed from one to the other. As one example, arsenic trioxide may be mentioned. It can be produced as a clear transparent glass which slowly changes at the ordinary temperature into an opaque white substance resembling porcelain in appearance. The opaque white substance is crystalline. It is the crystalline variety into which the vitreous will be slowly but completely changed. Again, if sulphur near its boiling point be poured in a thin stream into cold water it sets as plastic threads, and for our purposes we may speak of this as the vitreous form of sulphur; left at the ordinary temperature, it slowly changes into the crystalline form.

Two other examples may be given which, in a way, are perhaps more closely analogous with glass, since they are solutions of substances,

and not merely single substances as in the previous illustrations. Solutions of sodium acetate and Rochelle salt, obtained by adding to hot water as much of the salts as will dissolve and cooled so that no unfiltered air can enter the containing vessels, and carry nuclei to start crystallization, remain clear and fluid at the ordinary temperature. If such a "supersaturated" solution of sodium acetate be cooled in liquid air it is converted into a vitreous solid quite clear and transparent. On removal from the liquid air its temperature rises and very soon crystallization starts and proceeds right through the vitreous mass. The solution of Rochelle salt treated in the same way yields a similar vitreous mass, but as it warms up no crystallization takes place. It slowly goes back to the original liquid condition. The cold vitreous sodium acetate solution may be taken as analogous to a glass from which crystals readily separate on warming up, while the Rochelle salt is analogous to a glass which shows no tendency to crystallize through the whole range of temperature from the solid form to the point at which it is a mobile liquid. Glasses are known which tend to crystallize in all degrees of readiness. As a simple glassy substance, zinc silicate may be taken. It can be obtained, by moderately quick cooling of the molten mass, in a vitreous form which is stable for a number of years—at least, some has remained with no sign of crystallization at the ordinary temperature for 22 years. By heating to a few degrees above its softening point, it changes to a translucent crystalline mass. Taking a more complex glass, but still a moderately simple one, we may study the behavior of heat on a lime soda silicate glass. The specimen of greenish glass with some large and many smaller opaque nodules in it was given to me in the early part of the war by Mr. Frank Wood as an example of glass taken out of a tank furnace. The nodules are calcium silicate, which is the least fusible silicate potential in the glass. They have been formed through the glass in the particular part of the furnace from which it was taken being at a temperature too low to keep this silicate in solution or combination, and it has separated out in the form shown. To get this glass back to a complete vitreous state again would require a somewhat higher temperature than is used in the manufacture of the glass, since the calcium silicate is itself very infusible, and the rest of the glass has to be made very fluid before such masses of this silicate can be dissolved in any reasonable time.

This glass, then, in a molten state, is an example of a solution out of which a slightly soluble constituent has separated, when the conditions were suitable for that separation. It may be interesting to turn for a moment to a consideration of conditions for crystallization and to go back to simple glassy bodies such as zinc silicate and some borates. With all the vitreous substances which have been tried and

have been made to crystallize, there is a certain temperature at which crystallization proceeds readily, and for small ranges above or below that temperature no crystallization occurs. Associated with alteration of temperature, there is change in the viscosity of the vitreous substances, and hence in the freedom of movement of their particles among one another. The effect of this can be well seen when a crucible full of molten zinc silicate is removed from the furnace. If the mass be small so that cooling is quick, it remains a glass and has to be reheated before crystallization occurs. With a larger quantity and consequently slower cooling, the mass may become wholly crystalline, or only partly so if some of the vitreous form reaches a temperature at which its viscosity is too great, and freedom of movement of its particles too small for rearrangement into crystals to take place. Some borates are very convenient for illustrating the change from the vitreous to the crystalline state. Boric anhydride itself has not been made to crystallize, and as might be expected, the greater the proportion of it in a borate, the less marked is the tendency of a fused mass of that borate to crystallize on cooling. Of the three borates, $\text{CaO} \cdot 2\text{B}_2\text{O}_3$, $\text{CaO} \cdot \text{B}_2\text{O}_3$ and $2\text{CaO} \cdot \text{B}_2\text{O}_3$, the first can be obtained vitreous by fairly quick cooling, and pieces of it can, with care, be heated again to remove the strain produced, that is to say, it can be annealed. The second crystallizes from fusion much more readily, cooling has to be quicker to keep it in the vitreous state, and only small glassy pieces can be obtained, which crystallize, however, on attempting to anneal them. The third borate can only be kept vitreous in very small globules.

Statements, however, of the bulk which can be obtained of any readily crystallizable vitreous body require a certain reservation. It is well known that crystallizable bodies in the fluid state may be cooled considerably below the temperature at which they would ordinarily solidify to a crystalline mass, if they are freed from all foreign material. Water is a well known example, and among many others which could be cited, mention may be made of salol (phenyl salicylate). It melts at $43^\circ \text{C}.$, and if the crystallization of a film of the molten liquid be watched under the microscope, numerous small bubbles of gas can be seen to form during crystallization. The gas appears to be modified air. If salol be melted, allowed to solidify, and remelted in vacuo, so as to remove all this gas, and the process repeated several times, it is found that the molten salol must be cooled many degrees (50 or more) below its melting point before crystallization takes place. A small crystal of salol will start it unless, as can be done on small quantities, cooling has been carried far enough to increase the viscosity of the fluid to such an extent that the particles have not the freedom of movement necessary for

the change to the crystalline form. So it is also with a great number of glassy bodies, and the bulk which will retain the vitreous form can be largely increased since by fusion and crystallization several times they solidify at progressively lower temperatures, until the time comes when they get quite cold in the vitreous state. For instance, the amount of vitreous zinc silicate obtained has been raised from 20 grams at one heating up to a kilogram by 5 fusions. The calcium borate $2\text{CaO} \cdot \text{B}_2\text{O}_3$ has, after several fusions, been cooled to 500° below its ordinary solidifying point. When it does crystallize and the temperature rises the recalescence is remarkably bright. Long continued heating a few degrees above their solidifying points similarly retards the crystallization of many vitreous bodies, but it is not so effective as the alternate fusion and solidification. One reason at least is not far to seek, if the two processes be tried so that gases evolved can be pumped off and their amounts measured. The process with alternations yields much more gas in any given time. With all the glasses, simple silicates and borates, which have been studied so far, the chief gas evolved has been found to be water vapor, and with the progressive removal of it the vitreous state has been found to persist more and more. Direct introduction of water subsequently has been found to promote ready crystallization.

In connection with the comparison of long-continued heating of a melt with alternate fusion and solidification, one extreme instance is worth noting. For a special optical glass, rich in phosphoric anhydride, an experiment was tried with ammonium phosphate to find if this substance could be used in the batch mixture for the glass. A nice, clear fluid melt was obtained, which was kept fluid for several hours after all traces of gas bubbles had gone. The melt was well stirred and cooled till it was quite viscous, when it was left to get cold slowly. The next morning the furnace top was found forced off, and resting on a spongy mass of about thirty times the volume of the original glass melt. The changes occurring when solidification was approaching had evidently been accompanied by the evolution of a large volume of gas, no doubt most of it ammonia, since this substance was smelt on grinding the spongy mass up. The ground material was then fused and gave a stable glass.

Reverting to the question, Is glass truly vitreous, or is there evidence of any crystalline structure in it? and bearing in mind that glasses are known which exhibit all states of preparedness to yield crystals at some temperature or other, and that the tendency to the segregation of some ingredient of a glass is enhanced by the presence of small amounts of foreign substances and notably of water, one would rather expect to find a good many glasses in which some

evidence could be discovered of the early stages of orderly arrangement of particles toward the crystalline form. So far, etching glass surfaces with hydrofluoric acid has failed to reveal any of the network of crystalline structure filled in with vitreous material which is sometimes described as representing the texture of glass. Tearing the surface of glass by letting a film of strong glue dry and contract on it is also stated to reveal a crystalline network. Both the etching and this method give markings, very like a network, no doubt, but the figuring of the surface seems to be more correctly ascribable to surface tension. Nothing which could be called definite evidence of crystalline structure is visible with any kind of illumination under the microscope of such surfaces, but this is not to deny that the texture of some glasses may be that of a network of crystalline compounds inclosing vitreous bodies.

Certain facts, from which it appears reasonable to conclude that many glasses have something of a crystalline nature in them, have been obtained from a study of the phosphorescence of various glasses and other vitreous compounds exhibiting different degrees of readiness to pass into the crystalline state on heating. Much of the work was done about 20 years ago, but more recent experiments have not modified the conclusion then formed that a truly vitreous body exhibits no phosphorescence in ultra-violet light or X-rays or under cathodic discharge. Nearly every glass shows some phosphorescence and some show it very strongly, as, for example, the glass from which X-ray bulbs are largely made, and which gives the well-known green glow when the tube is in use. If some of this glass be fused and very rapidly chilled, as, for example, by making a Rupert's drop from it, the glass is practically nonphosphorescent so far as its surface is concerned. A very little distance below the surface the chilling was not sudden enough to prevent some change of the truly vitreous to an attempt at crystalline structure, so that just below the surface, as shown by broken pieces of the drop, the glass exhibits phosphorescence. The tail of such a Rupert's drop, if heated below the temperature at which the thin thread of glass bends, is found to be strongly phosphorescent, and the glow under cathode discharge can be seen to fade slowly away toward the part which was not heated. Many observations with vitreous borates and silicates have shown similar phosphorescence, appearing more and more strongly as the vitreous bodies are made to approach the crystallizing stage. There does seem, therefore, reason to state that, given a body which in its crystalline state exhibits phosphorescence, it will not do so when it is in a truly vitreous state, and to infer that if a glass be phosphorescent there is something of a crystalline nature in it. It would not be right to come to the conclusion that a glass showing no phos-

phorescence is free from anything crystalline, since there may be crystalline structure in it which is not in the sensitive state to be revealed by phosphorescence. It would take up too much time to elaborate this further, but generally it may be said that a number of experiments on glasses, borates, etc., go to show that in some non-phosphorescent glasses there is most likely some crystalline formation, since the introduction of minute amounts of certain bodies not usually present in these glasses, as manufactured, will render them quite markedly phosphorescent; and again, the surfaces of Rupert's drops made from these sensitive glasses show no phosphorescence. Before going on to deal shortly with some points about devitrification, I may point out that boric anhydride, which has a marked effect in preventing crystallization in glasses and in enhancing the stability of the vitreous form, is a fatal ingredient to add to a uranium glass if strong fluorescence in ultra-violet light be aimed at.

It may be concluded from what has been said or suggested that the question whether glass is crystalline or not has a bearing on the problem of devising, manufacturing, and annealing optical glasses. It has, perhaps, a more obvious bearing on the problem of producing glasses capable of being freely worked in a furnace or in the flame of a blowpipe. To the flame worker especially, a glass prone to devitrification is a source of trouble. It would take at least a whole lecture to deal adequately with all the changes noticed in the numerous types of glasses which have been studied for their behavior in the flame. I will confine myself merely to mentioning that the segregation of less fusible vitreous bodies giving a kind of crinkled skin to the glass, separation of amorphous silicates, the formation of very minute bubbles giving a gray look to the glass, as well as true crystallization, are all frequently referred to as devitrification. It is mainly about the last form of it that there is time in this lecture for a few remarks.

There is great variety in the behavior of glasses in a flame. A soda-lime silicate can be made which is hardly workable at all in the flame, it devitrifies so soon; but the same glass may be worked, if heated by radiation—for instance, in a muffle furnace. At the same time, it must be understood that exposure in the muffle may bring about devitrification even quickly if the temperature is such as to bring the glass to the right state of fluidity for rearrangement of some of its particles in the crystalline form. It would appear, therefore, that the difference between the behavior of the glass heated in the flame, and heated by radiation, may be explained by the difference in temperature reached by the glass in each case, and no doubt this is a most important part of the explanation. Recalling what was said, however, about the conditions for crystallization of vitreous bodies, there is, apart from temperature, the question of purity to be taken

into account. The problem is whether the readier devitrification of a glass in the flame can be ascribed solely to the surface of the glass being exposed to a very high temperature, and so for a thin layer reaching the right state of fluidity for crystallization or whether chemical action also plays a part, i. e., whether the hot gases of the flame act on the glass and assist the segregation of parts of it by disturbing the chemical equilibrium of the bases and acids of the glass. Attempts to get an exact reproduction of the behavior of a glass in a flame by exposure of thin pieces of the same glass to intense heat by radiation, have given results showing close similarity in some glasses and great differences in others. It would be somewhat out of place, and certainly tedious in a lecture such as this, to go into the details which seem to justify the statement that a survey of the relative behaviors of a very large number of different types of glasses exposed to flames or to heat by radiation, and chemical examination of the products, leads to the conclusion that water, and to a smaller extent carbon dioxide, do act chemically when many glasses are heated in flames, and that this action plays an important part in the initial stages at least of devitrification. As the most simple example, which I can choose, of marked difference in composition of a glassy body heated by radiation, or in a blowpipe flame, ordinary borax, $\text{Na}_2\text{O} \cdot 2\text{B}_2\text{O}_3$, may be taken. Heated in a muffle up to about $1,450^\circ \text{C}$. until much of it has volatilized, the residue may, according to the time of heating and the temperature, have a composition represented by anything between $\text{Na}_2\text{O} \cdot 0.8\text{B}_2\text{O}_3$ to $\text{Na}_2\text{O} \cdot 1.5\text{B}_2\text{O}_3$; but it has not been found possible, under any conditions, in a blowpipe flame, to get a residue from borax with the proportion of boric anhydride greater than is represented by about $\text{Na}_2\text{O} \cdot 0.3\text{B}_2\text{O}_3$. It is difficult to ascribe this difference solely to the effect of different temperatures. With some glasses, however, there is visible evidence of the disturbing influence of the hot gases of the flame. A glass containing barium oxide, which was heated and reheated many times by radiation of varying intensity, and which was most reluctant to show any signs of crystallization, became, in the blowpipe flame, or in a hydrogen flame, gray at once over its surface, and soon afterwards signs of crystallization were readily noticeable. The initial gray effect was seen under the microscope to be due to numerous very minute bubbles caused apparently by the rapid absorption and subsequent evolution of gases. As the question considered here is the influence of the hot gases of a flame to hasten devitrification, there is no occasion to discuss the well-known effect of an ordinary blowpipe flame to blacken glasses containing lead or similarly reducible metals, except to say that experiments show that in many instances the process of alternate reduction and oxidation which sometimes occurs when such glasses

are being worked in the flame, does also appear to hasten devitrification.

Mention was made above of the influence of boric anhydride to retard the crystallization of glasses in which it is an ingredient. Alumina is another substance the presence of which confers upon a glass the property of working well in the flame without devitrification. More striking, perhaps, as a vitrifying agent is titanic oxide. A soda-lime silicate glass was made which could not be worked in a flame at all so readily did it devitrify. The substitution of a small amount of its silica by titanic oxide converted the glass into one which could be heated and worked in the flame almost indefinitely without visible change. The statement "without visible change" is true of the behavior of this glass; but some, and notably very soft glasses containing titanic oxide, become colored in the ordinary blowpipe flame through reduction of this oxide to a lower state of oxidation. Zirconium, tin, and thorium oxides have been found to promote the stability of the vitreous state in a number of glasses prone to devitrification in the flame. They are mentioned as being of the same chemical family as silica and titanic oxide; but to deal with the effect of a number of rarer compounds not generally employed in glass-making would take up too much of the rest of the time at my disposal. Arsenic and antimony oxides may also be put among substances which render glasses less liable to devitrification; but glasses containing these oxides are not suitable for ordinary working in the blowpipe, since they darken in the reducing area of the flame. Tin oxide, mentioned above, is also not a generally suitable ingredient, since some glasses containing it darken badly through reduction in the flame, though others can be made which are quite workable except in the hottest kind of blowpipe flame.

I must leave out of consideration the relation of general composition and of varying proportions of ingredients to the tendency of glasses to devitrify, and content myself with the remark that for glasses of comparable composition those containing soda only as the alkali, are usually found to devitrify more readily in the flame than those in which the alkali is potash, or a good proportion of potash with soda.

In this lecture it will only be possible to deal more or less briefly with opal and colored glasses. Many vitreous bodies which crystallize fairly readily when heated can be seen to pass through a stage in which the material segregating from them appears first as an opalescence increasing in density as the heating is continued and finally passing into a visibly crystalline form. A glass approximating in composition to $\text{Na}_2\text{O} \cdot \text{CaO} \cdot 3\text{SiO}_2$ shows this opalescence well before small crystalline nodules appear similar to those in the tank glass

referred to earlier. Various silicates and borates of calcium, barium, and magnesium show the same kind of phenomenon more readily and by quickly cooling when a stage of dense opal appearance is reached, sections (or, what is just as good for the purpose, the finely ground glassy material mounted in Canada balsam) can be examined under the microscope and the opal effect shown to be due to the scattering of light by numerous small transparent globules. Any glass from which, on cooling, part of it segregates out in very small particles evenly diffused through the mass, may be called an opal glass whether the fine particles are crystalline or amorphous, but the usual opals owe their milkiess to globules in which no evidence at least of the crystalline state can be found. Under the microscope the globules, if sufficiently visible as distinct particles, appear vitreous and transparent, just as in milk the fat globules are seen to be themselves colorless and transparent. Among the many substances which can be used to produce opal glasses, the most common are fluorides such as calcium fluoride, cryolite (the double fluoride of sodium and aluminium), and calcium or sodium phosphate, less commonly the arsenates of these metals. These substances can be included in the batch mixtures of ordinary soda or potash lime glasses, or lead glasses or zinc glasses. In the making, opal glasses are usually clear at a high temperature and "strike" opal on cooling. To what extent the glass has to be cooled before becoming opal depends on the concentration of the particular opal-producing compound which is held in solution in the very hot glass. Opal glasses produced with phosphates "strike," generally speaking, at higher temperatures than those made with fluorides, the compounds formed in the glass by the latter being more soluble than those due to phosphates, at least in the case of most opal glasses made on a commercial scale. Whatever opal-forming material is potential in the molten glass, if its concentration be great, the glass "strikes" opal quickly and with relatively little cooling and becomes a denser opal as cooling proceeds, until the stage is reached when no more material segregates. Just, however, as in the crystallization of an ingredient in a glass, cooling may occur so quickly that a state of viscosity is reached in which crystallization can not proceed, so with opal glasses the concentration of the opal-producing material may be such that only a little of it comes out of solution before the viscosity of the glass gets too great to allow of further separation. With still less concentration, moderate-sized pieces of the glass may even solidify in a perfectly clear condition, but again, just as reheating will often cause a glass which has cooled vitreous to become more or less crystalline, so reheating the intended opal glass will cause it to "strike." This can be illustrated by blowing a bulb from a tube of an opal glass. If the bulb be not too thick,

and the concentration of the opal-forming material be not too great, the glass will go quite clear in the flame and the blown bulb will remain quite clear on cooling. If the bulb be then again heated gradually in a flame, the whole process from a mere trace of opalescence to a very dense opal can be watched. If during the various stages of opacity the light transmitted through the glass be observed, it will be seen to change from light orange yellow to darker and darker orange and orange red, until no more evidence of color is seen, but only a general translucence. If thin sections (or ground-up pieces mounted in Canada balsam) of the opal glass in the various stages be examined under the microscope no separate particles in the earlier stages will be seen, even with lenses of large angular aperture, though their existence can be inferred from the opalescence which is to be well seen under the microscope with suitable black ground illumination. In the later stages of denser opal, separate particles are visible, and are seen to be progressively larger as the density of the opal is greater and greater.

When an opal glass is required for articles, the making of which involves working the glass in a muffle or in the flame, it is important that the separated globules shall not tend to aggregate or to pass into the crystalline state, otherwise the glass is found to have a rough surface. To guard against this, too great concentration of the opal-forming material must be avoided, and some workers prefer a glass which does not reach its full opal until it has been in the annealing oven. As a general experience with a wide range of all kinds of opals, it would appear that fluoride opals are more kindly in working than phosphate opals. This is more especially true for the denser kinds of opal. For merely opalescent glasses, phosphates give quite good results, but with greater concentration of the opal-forming substance there is a tendency toward crystallization, which is more marked as a rule in the phosphate than in the fluoride opals. A dense opal suitable for working in a flame should "strike" opal even in thin pieces on removal from the flame, and should stand long-continued heating without losing its fine polished surface. When such a glass while opal is drawn out into a rod and longitudinal sections of the rod are examined under the microscope, the globules are to be seen egg-shaped or even elongated into minute rods. If an end of the opal rod be heated again to softening point and sections of that end be examined, the opal-forming material is seen to have gone back to spheres, showing that even when separated out the opal material has about the same softening point as the rest of the glass. It is easily to be understood that if it has not, and the globules are of appreciable size, a glass containing them can not be worked without roughening. One more point may be mentioned before concluding

this short general account of opals. A glass may be required which, while remaining clear in thin pieces after removal from the flame, will "strike" on reheating so readily that the temperature needed to develop the full density of the opal is not high enough appreciably to soften the glass and so cause deformation. One way of securing this behavior is to add as an ingredient a small amount of a substance which will produce a trace of a compound insoluble in the glass except at very high temperatures. In the flame this compound persists as a slight turbidity and appears to facilitate the "striking" by affording nuclei on which the opal material can collect.

Colored glasses are sometimes divided into two main groups: (*a*) Those in which the coloring matter is diffused in very small particles throughout the glass, and which may be likened to colloidal solutions; and (*b*) those in which the coloring substances are in a state resembling that of solution, and which may be likened more nearly to aqueous solutions of colored salts. Just, however, as in aqueous solutions there may be traced or inferred all grades of subdivision of the coloring matter from separate particles which can be revealed by their scattering action on light, and which may be seen in the ultra microscope through smaller and smaller particles scattering light less and less obviously down to those in the extreme state of subdivision frequently described as that of true solution, so in glasses similar grades of subdivision of their coloring matter may be seen or inferred.

It is in fact impossible sharply to divide colored glasses into these two groups; but it can be said of certain glasses that they are typical of group (*a*), and among the more common of these may be mentioned those owing their colors to the presence of gold, copper, and selenium. It is generally considered that these coloring agents exist in the glasses as metallic gold, metallic copper and elementary selenium respectively, and the varying colors which can be obtained in each case appear to depend on the state of division of the coloring agents, or at least to be associated with it. How far there is evidence that selective absorption of light has also to be taken into account, is a question which can hardly be dealt with in a short time.

With gold the colors most readily obtainable range from red to blue through varying stages of purples. With copper in the metallic state the common color is red; but it is possible to get variations very similar to those seen in gold glass, and a copper glass giving a definite blue by transmitted light has been obtained. It is to be understood that this blue was not due to copper in an oxidized condition, but to metallic copper. Selenium glasses are also generally red, but again states of division of this material can be secured which give other colors, although it is difficult, except on a very small scale,

to obtain other than grays or neutral tints. With each of the glasses in which gold, or copper, or selenium is present, quick chilling of the molten glass will, as in the case of opal glasses, yield a clear and colorless glass, and the greater the concentration of the coloring agents, the more sudden must the chilling be to secure this result. On reheating these colorless glasses they, like the opals, "strike" and yield the colors which could have been obtained by slower cooling of the molten glasses. It may be of interest to deal with a gold glass a little more in detail. It is not easy to get a strongly colored glass with gold added, in the form of gold chloride, to the batch mixture of an ordinary soda lime glass. Among the substances which enable one to prevent gold separating from the molten glass in the ordinary metallic state the commonest used are the oxides of lead, tin, and antimony. Bismuth oxide acts similarly, and so also does uranyl oxide. There are physical and chemical problems of much interest involved in this behavior of these oxides; but it would lead us too far into technical details to attempt their discussion here. A gold glass containing oxide of tin may be chosen, because it can be made so that its behavior can be studied either in the furnace or in a blowpipe flame. With a suitable concentration of the gold, and very slow cooling of the melt, all the ranges from red by transmitted light to a pale blue can be observed, and if rods are drawn out from the pot at intervals, and examined in a beam of light, it will be seen that, starting from a fine deep red by transmitted light through the various stages of reddish and blueish purple and blue to the pale blue, there is progressively more and more marked scattering of the light, and the rods look more and more of an opaque brown color by reflected light, until in the later stages the appearance of precipitated gold is so marked as to leave no doubt that what has occurred has been a progressive aggregation of the gold into larger and larger particles. Microscopical examination of the glass at the different stages gives clear confirmation of this and of the great similarity in the manner of separation of the gold to that of the materials which give opal glasses. Remarks made under opals and crystallization of glasses about the influence of changing viscosities apply also, in a general way, to gold glass. There is one point in this connection which is worth referring to. If the suddenly chilled and colorless glass be returned, in small pieces at a time, to a pot in a furnace at a high temperature, about 1400°C. , the glass can be melted and the gold still retained in it without appreciable loss by separation into the ordinary metallic state; but if it be slowly heated up it passes through the stages of color previously described and, after complete fusion at a high temperature, practically all the gold will be found in a button at the bottom of the pot. Now, except in the

case of a very soft gold glass, heating and working the colorless glass in the flame will only give a red glass, and no passage through the other stages is seen, or, in general, if the glass at any of the stages of color be worked in the flame, the change of color is but slight. The explanation seems to be that, throughout the mass of the glass the temperature never reaches high enough to give the state of viscosity for free aggregation of the gold particles, while, on the immediate surface of the glass the temperature may be so high that the gold is retained in solution, as it is in the highly heated furnace. It is very difficult to get a gold glass to behave like some opal glasses, in the sense that it will go clear and colorless in the flame and remain so when quickly cooled; but a copper glass can be made in a similar manner with tin oxide, which will go quite colorless in the flame. Bulbs can be blown from it which remain white on cooling, and the gradual "striking" of a deep red color observed on gently reheating in the flame. It has been noticed in experiments with some copper glasses that, in the initial stages of "striking" the color which develops is not red, but a dark neutral tint with a suggestion of olive green in it. This may be from copper in the very finest state of division in which it can exert visible action on light, or it may be due to the presence of traces of oxidized copper in the glass giving rise to the well-known dark compounds of cuprous and cupric copper. Certainly very dark glasses of rather similar tint can be obtained by intentionally allowing some oxidation to take place in the making of a red copper glass, or by fusing together a reduced copper glass with one in which the copper is fully oxidized. At the same time it is worth noting, and is perhaps suggestive, that a chilled and colorless gold glass which goes through the stages of very pale red to a fine full red on heating in the flame has, after six months' exposure to the β -rays of radium, only developed a dusky neutral tint. A piece of glass of the same composition, except that there was no gold at all in it, has not been affected by the radium. It would lead too much into theoretical discussion to consider in what form gold, copper, and selenium exist in the respective chilled and colorless glasses, and how far they may be looked upon as being in combination, or merely in so fine a state of division, that they have no visible effect on light. The chemical and physical evidence that, when they do give color they are in the elementary state seems to be fairly conclusive; but this does not necessarily exclude the possibility of their being in something very like chemical combination in their colorless states.

Perhaps it is needlessly striving after definiteness to attempt to distinguish between bodies being dispersed in an extremely fine state of division, partly at least through chemical attraction for their solvent, and being held in a loose kind of chemical combination.

Some consideration of such a question, however, is helpful in suggesting experiments, and some instances may be given. One is in connection with the composition of a glass to give the full possible color with copper. The notion of something like chemical combination of the copper leads to the study of the effect of varying the relative amounts of the basic and acid ingredients of the glass. More of the basic part, such as the alkalies, might be expected to turn the copper out of combination, and more of the acid part to keep it in. It would be tedious to describe in detail the results of numerous trials with glasses, and the point can be equally well illustrated by simple experiments with borax beads. Copper oxide mixed with about twice its weight of tin oxide can be dissolved in molten borax in an oxidizing flame and then reduced in a reducing flame. On cooling, the bead is either colorless or "strikes" red, according to the concentration of the copper. If colorless, it can, with suitable concentration, be made to "strike" by reheating. Now, if to the bead which "struck" red on cooling, more boric anhydride be added, and the bead again fused, it will remain colorless on cooling; but unless too much boric anhydride has been added it will "strike" red on reheating. Addition now of more alkali, in the form of sodium carbonate, will restore the property of striking red at once on cooling. Similarly it follows that a bead which remains colorless on cooling, but "strikes" on reheating, can be prevented from giving any color of copper at all by more boric anhydride, and the property of "striking" red on reheating can be restored by the further addition of alkali. Of course, in making these various additions of alkali and acid to the bead there must be a change in the concentration of the copper; but a bead can be got in so sensitive a condition that a mere trace of alkali will determine whether a red color is developed or not, and a number of experiments on glasses and glazes do confirm the notion of chemical action playing a part on lines which would be expected from general chemical experience.

When manganese dioxide is added to a glass as a so-called decolorizing agent, it is intended to be left in an oxidized condition, so as to give a violet color which will disguise the green color due to iron and produce only a slight darkening of a neutral tint, scarcely visible except in thick pieces of the glass. Sometimes the violet tint is overdone and can easily be seen, and sometimes so much of the manganese dioxide has been reduced that the green due to iron is fully visible, the lower oxide of manganese giving no color to the glass. In many instances of glasses in which one would be inclined from mere inspection to say that all the manganese dioxide had been reduced in the furnace, it has been found that a strong violet color can be developed by exposure to radium or by cathode discharge in vacuum tubes. In parenthesis it may be

remarked that potash glasses generally give a good violet and soda glasses a brown or a brownish violet. Using small amounts of manganese dioxide in batch mixtures, as free as possible from iron, it has been found possible to get glasses practically colorless to the eye, some of which readily give color on exposure to radium for a period during which others develop no color. In making the latter, the conditions in the furnace were arranged for complete reduction of the manganese dioxide. In making the former, as little deoxidation as possible was aimed at. In one instance thin rods drawn from the melt of one of these, in which very little manganese dioxide was used, cooled almost colorless, but "struck" quite a marked violet color on reheating. This chilled glass was also very sensitive to radium. More urgent work prevented further experiments, but the facts so far obtained are mentioned as relevant to the question of the chemical condition of coloring agents in glasses, and as an illustration of one which would appear to be somewhat of a border line example of the groups (a) and (b), referred to previously. I am reluctant to dismiss the matter in this rather summary fashion, but the interesting speculations which will occur to many can hardly be dealt with shortly. I would, however, recall the well-known pink or violet color to be seen in some window glasses which have been exposed for years to daylight. In all examples which I have been able to examine, manganese has been found to be present, and I can imagine that the color has developed in daylight in a manner similar to that in which it has been found to be developable in manganese glasses by radium, by cathode discharge, or by heat. The color of the old window glasses is a little puzzling, if they are soda-lime glasses. One would expect them to be browner in tint; but perhaps on insufficient grounds, since no direct experiments have, so far as I know, been made with manganese glasses made with potash and with soda-batch mixtures and exposed to sunlight for a long period. It is a matter for regret that when the old tinted window glasses were examined for manganese the idea of the influence on the color of the alkalis present did not occur. [Having regard to the effect of manganese greatly to enhance the phosphorescence of potash and soda-lime glasses, and to the known coloration of certain potassium and sodium compounds under cathode discharge, it is possible that the colors in the old window glasses described are not due to manganese dioxide itself, but that manganese may have rendered the alkali compounds in the glasses more sensitive to light of short wave lengths. The fact that glasses containing no manganese did not color under cathode discharge, etc., is not conclusive, since such glasses showed but feeble phosphorescence. The observation, however, that of two glasses containing the same amount of manganese, and giving equal phosphorescence, the one in which there is evidence of some

of the manganese being in the higher state of oxidation becomes very markedly colored by an amount of exposure to rays which has no visible effect on the other glass in which the lower oxide of manganese only is present, seems at least to point to some special behavior of manganese dioxide.]

The influence of different alkalis and the remarks already made on the effect of varying the relative proportions of bases and acids on the copper glasses bring me to a short consideration of the behavior of coloring agents which would generally be placed in group (b) as existing in glasses in a state more nearly resembling that of true solution than that which may be considered to obtain in the more colloidal solutions of gold, copper, selenium, and other substances such as silver, sulphur, carbon, etc., with which there has been no time to deal. I must confine my remarks to but few of group (b), and perhaps nickel and cobalt will be the most suitable to illustrate the effect of different alkalis and also that of varying proportions of one and the same alkali.

If three similar and moderately soft glasses be made containing, respectively, potash, soda, and lithia as the alkalis present in chemically equivalent proportions, and if the same amount of nickel oxide be present in each glass, marked difference in the colors is observed. The potash glass is a fine deep violet, the soda glass is almost brown, with only a hint of purple in the brown, and the lithia glass is a yellowish brown, with less strength of color altogether in it than there is in the soda glass. Similar differences can be seen in beads made from nickel oxide dissolved in the bi-borates of the three alkalis. Of these alkalis potash is the strongest and lithia the weakest base. The glasses mentioned would not be described as acid glasses, but as glasses containing a fair proportion of basic to acid ingredients. If highly acid glasses be made with the three alkalis and the same proportion of nickel oxide, the lithia glass is only slightly colored a brownish yellow, the soda glass is a lighter brown, with no trace of purple in it, and the potash glass is rather darker in shade than the soda glass, but a definite brown. Again, very similar results can be obtained in beads of the borates of the alkalis by varying the proportions of acid and alkali, and using the same amount of nickel oxide in each set of experiments. With potash as the alkali the proportion of boric anhydride and alkali and the concentration of nickel oxide can readily be adjusted to show a bead colored brown when cold, but becoming a definite violet when heated just below a dull red heat. A like change of color has been observed in experimental glasses made for studying the colors obtainable from nickel.

With cobalt oxide as the coloring agent, the difference between the blue colors of potash and soda soft glasses is not very noticeable; but a similar lithia glass is less colored, and there is an appreciable

violet tint in the color. If, however, using any one of the three alkalis, a highly acid glass containing the same amount of cobalt oxide be made, the difference between it and the comparable soft glass is very marked. There is much less depth of color altogether. What there is is a somewhat violet blue in the case of the potash glass, a rather lighter and more violet blue in the soda glass, and a still lighter pink violet in the lithia glass. This nearly pink glass goes to a weak but quite distinct blue when heated.

The effect of the alkalis potash and soda on the color of borates is not so marked in the case of cobalt as it is in that of nickel. Lithia in comparison with them always gives for equivalent proportions a much more decided violet tint in the blue. The influence of the proportion of base to acid, however, is marked, and can be very well seen by using any one of the alkalis in varying proportions with molten boric anhydride, to which a small amount of cobalt oxide (about 0.25 per cent) has been added. [Cobalt oxide dissolves in highly heated boric anhydride, but on cooling cobalt borate separates out, giving an opaque, very pale blue, glassy mass.] Taking lithium carbonate as the alkali and adding only a very small amount (about 0.25 per cent) the whole of the cobalt remains in solution on cooling, and the resulting glass is seen to be blue while still hot, to change to a more and more violet tint on cooling, and to be almost a pink when cold. The addition of more of the alkali intensifies the blue color, giving greater depth of color, and the mass when cold is a violet blue. Similar variations in color can be obtained with equivalent quantities of potash and soda, but the effect of these alkalis is always to give a more pronounced blue as the amount of alkali is increased. Comparing the weakest base, lithia, then, with potash, the strongest, and progressively adding each to borate beads containing cobalt, no amount of lithia, up to the point when it is impossible to keep the bead vitreous, will give as blue and as strongly colored a bead as the equivalent, or even less than the equivalent, of potash will produce. There is always a more violet tint in the lithia bead.

In conclusion, a brief reference may be made to another coloring agent, copper oxide. This oxide is not soluble in boric anhydride when a bead of the latter is heated in an oxidizing flame, but by the addition of an alkali a clear blue bead is obtained. Should the alkali, e. g., potash, be added in very small amount, so as to give a highly acid mixture of about the composition, for instance, represented by the portions $K_2O.5OB_2O_3$, the coloration due to about 0.25 per cent of copper oxide is so faint that the bead is practically colorless, although this amount of the oxide is sufficient to give a markedly blue bead in potassium bi-borate, $K_2O.2B_2O_3$. In this case, also, then the color becomes more intense as the amount of alkali used is increased.

One is tempted to compare this effect of alkali on the copper oxide and boric anhydride mixture with that of water on copper sulphate, which, in the anhydrous state, represented by the formula CuSO_4 , is white. The addition of water sufficient to give the composition $\text{CuSO}_4 \cdot \text{H}_2\text{O}$ leaves the substance still white; but with more water the well-known blue copper sulphate $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ is produced. Without going so far as to call this an example of hydrolysis by water, it may not be too much to speak of the development of color as indicating in $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ a greater tendency to the formation of blue copper hydroxide than is possible with the smaller mass of water in $\text{CuSO}_4 \cdot \text{H}_2\text{O}$.

The notion that there is an analogy here with the progressive development of color in glasses and borates with increase of alkali may be suggested, but with reservations. Still, the changes from brown to violet in the case of nickel, from pink to blue in the case of cobalt, and the progressive development of the color of copper, all brought about by increasing the proportion of alkali, do seem to point, if not to a definite separation out of the oxides of these metals, to something like it in the sense that with very little of the alkali present the oxides of the metals may be playing a basic part, but are turned out by more of the stronger base (the alkali), and may be either freed or caused to play the part of acids to the alkali. The study of a wide range of coloring agents in glasses has furnished some facts which, from a chemical point of view, lend plausibility to the notion and others which seem to need a great deal of interpretation to support it. As an idea it has been useful in suggesting methods of producing as well as preventing color in glasses. More facts, however, must be accumulated for a fuller and more correct shaping, in its physical and chemical aspects, of one of the many interesting problems connected with glass.



THE FUNCTIONS AND IDEALS OF A NATIONAL GEOLOGICAL SURVEY.¹

By F. L. RANSOME, *United States Geological Survey.*

INTRODUCTION.

During the period of unrest and uncertainty through which we are still painfully groping the many distracting calls upon my time and thoughts have made performance of the duty to prepare a presidential address particularly difficult. In view of these circumstances I may perhaps hope for your indulgence if my effort shows some lack of thoroughness in its preparation and falls short of the high standard set by some of my distinguished predecessors. The subject of a presidential address to the academy should, I think, be of wider interest and more general character than would ordinarily be an account of work in the speaker's particular branch of science, and this condition I have attempted to fulfill. Although what follows will deal especially with national geological surveys, much of it will apply in principle to any scientific bureau conducted as a Government organization.

REASONS FOR THE EXISTENCE OF A NATIONAL GEOLOGICAL SURVEY.

In the beginning it may be well to review briefly the reasons for the existence of a national geological survey. Why should the Government undertake work in geology while it leaves investigations in other sciences to private initiation and enterprise? The reasons that may be adduced will differ with the point of view. The geologist will suggest that whereas some sciences, such as chemistry, physics, or astronomy, may be pursued successfully with stationary and permanent equipment at any one of a number of localities, geology is regional in its scope and is primarily a field science as contrasted with a laboratory science. Geology, it is true, must avail itself of laboratory resources and methods, but the geologist can not have the greater part of his material brought to him; he must himself seek it afield. Thus it comes about that comprehensive geologic

¹ Address of the retiring president of the academy delivered Jan. 13, 1920. Reprinted by permission from the Journal of the Washington Academy of Sciences, vol. 10, No. 4, Feb. 19, 1920.

problems require for their solution the equipment of more or less expensive expeditions or travel over large areas. Such projects, as a rule, can not be undertaken by individual geologists or by local organizations. The preparation of a geologic map of a whole country, with its explanatory text, generally recognized as essential fundamental work, is an undertaking that requires consistent effort by a central organization extending over a period of years. Such a map is not likely to result from the patching together of the results of uncoordinated local effort. From a broadly utilitarian point of view the intelligent layman as well as the geologist must recognize that the development of a country's natural resources in such a manner as to secure their maximum use for the greatest number of its citizens necessarily depends upon reliable information concerning the character, location, and extent of these resources and that this information should be available before they are exploited by those who have eyes only for their own immediate profit or before they pass entirely into private control or are exhausted. Such information can best be obtained and published by an impartial national organization responsible for its results to the people as a whole. Such a layman will recognize also that knowledge of the mineral resources of a country must rest upon a geological foundation. As Prof. J. C. Branner has recently said in his "Outlines of the Geology of Brazil":

After a life spent chiefly in active geologic work and in the direction of such work I should be remiss in my duty to Brazil if I did not use this occasion to urge on Brazilian statesmen the serious necessity for the active encouragement and support of scientific geologic work on the part of the National and State Governments. Knowledge must precede the application of knowledge in geology as well as in other matters; and unless the development of the country's mineral resources be based on and proceed from a scientific knowledge of its geology there must inevitably be waste of effort, loss of money, and the delay of national progress inseparable from haphazard methods.¹

Finally the citizen of narrower vision will regard as sufficient justification for a national geological survey the fact that he himself can turn to it for information and assistance in the development of particular mineral deposits to his own material advantage.

As a matter of fact most of the progressive countries of the world maintain geological surveys, so that the desirability of such an organization appears to have been generally recognized, whatever may have been the particular reason or reasons that set in motion the machinery of organization in each country.

Recognizing the fact that most of the principal countries have established geological surveys and granting that there are good reasons for considering the maintenance of such an organization

¹ J. C. Branner, *Outlines of the geology of Brazil*, Geol. Soc. Amer. Bull. 30:194. 1919.

as a proper governmental function, we may next inquire, What should be the ideals and duties of a geological survey? How may these ideals be realized and these duties performed?

GENERAL LEGAL FUNCTIONS.

The organic act of the United States Geological Survey specifies indirectly and in general terms the field that the organization should occupy. It states, with reference to the director, "this officer shall have the direction of the Geological Survey and the classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain."

Doubtless the laws or decrees under which other national geological surveys have been established also prescribe to some extent their duties. Such legal authorization, however, is as a rule so general as to leave room for considerable latitude in its interpretation. I propose first to discuss the functions of a national geological survey without reference to legal prescription or definition and afterwards to consider the extent to which some of the actual conditions interfere with the realization of these ideals.

USEFULNESS IN SCIENCE.

It has been the fashion in some quarters of late to emphasize usefulness as the chief criterion by which to judge the value of scientific research under Government auspices. It has been intimated that this or that scientific bureau of the Government must do "useful" work if it is to justify its existence and its expenditure of public funds. The statement is usually made with an air of finality, as if a troublesome question had been once for all disposed of and the path of the future made plain. As a matter of fact, however, when it is said that science must be useful in order to receive Government support we have really made very little advance. Probably the most idealistic scientific man will admit that ultimate usefulness is the justification for scientific research, although that end may not enter into his thoughts when he undertakes any particular investigation with the hope of increasing human knowledge. Men will differ very widely, however, as to what is meant by usefulness in science. It is well known to all scientific men, although not yet as widely recognized by others as it should be, that the utility of research is not generally predictable. For example, the investigations on electricity for hundreds of years preceding the middle of the nineteenth century had, so far as could be seen, no practical bearing. The experiments of Volta, of Galvani, and even those of our own Franklin, outside of his invention of the lightning rod, were not conducted with any thought of utility and were probably looked

upon by the people of the time as diversions of the learned, not likely to have much effect upon human life and progress. How erroneous such a view was it is unnecessary to point out to a generation accustomed to daily use of the trolley car, telegraph, telephone, and electric light. Not only is the utility of science not always predictable, but it is of very different kinds. That astronomy has certain practical applications in navigation and geodesy is well known; but important as these applications are they seem insignificant in comparison with the debt that we owe to this science for enlarging our intellectual horizon. This, too, is usefulness which I venture to think is of a truer and higher sort than much that passes current for utility. The classic researches of Pasteur on the tartaric acids, on fermentation, on the anthrax bacillus, on the silkworm disease, and on rabies were so-called applied science of the very highest type, indistinguishable in the spirit and method of their pursuit from investigations in pure science. They were not merely the application of knowledge to industry, but were extraordinarily fruitful scientific investigations undertaken to solve particular industrial and humanitarian problems. They are especially interesting in the present connection as probably the most conspicuous example in the history of research of the merging of pure and applied science. Pasteur was doubly fortunate in that he not only enormously enlarged human knowledge but was able to see, at least in part, the practical application of his discoveries to the benefit of humanity. The value of his results measurable in dollars is enormous, yet this is not their only value. Prof. Arthur Schuster, in a recent address, remarks:

The researches of Pasteur, Lister, and their followers, are triumphs of science applied directly to the benefit of mankind; but I fancy that their hold on our imagination is mainly due to the new vista opened out on the nature of disease, the marvelous workings of the lower forms of life, and the almost human attributes of blood corpuscles, which have been disclosed.

The effect on a community is only the summation of the effect on individuals, and if we judge by individuals there can be little doubt that, except under the stress of abnormal circumstances, pure knowledge has as great a hold upon the public mind as the story of its applications.

Quite independently of any recognized usefulness, investigations that yield results that are of interest to the public are willingly supported by the people, and this fact is significant in connection with what I shall have to say later on the function of education. As illustrations of this truth may be cited our Government Bureau of Ethnology and our large public museums. Probably few who read the admirable Government reports on the aboriginal antiquities of our country and on the arts and customs of the Indian tribes could point out any particular usefulness in these studies; but they have to do with human life, and their popular appeal is undeniable. The

average visitor to a museum probably has little conception of what to a scientific man is the real purpose of such an institution. He gazes with interest at the contents of the display cases without realizing that by far the greater part of the material upon which the scientific staff is working or upon which investigators will work in future is hidden away in drawers and packing cases. The principal recognizable result, so far as he is concerned, is that he is interested in what he sees and feels that he is being pleasantly instructed.

In other words, it is as important for man to have his imagination quickened as to have his bodily needs supplied, and in ministering to either requirement science is entitled to be called useful or valuable.

It may be remarked in passing that Pasteur's work had this in common with pure science, or science pursued with the single aim of adding to human knowledge, in that Pasteur himself could not foresee all of the applications that would in future be made of his discoveries.

Enough, I think, has been said to show that the term "usefulness" as applied to science covers a wide range and that when employed by people of imagination and liberal culture it may include much more than when used by those whose only standard of value is the unstable dollar.

FUNCTIONS UNDER AN IDEAL AUTOCRACY.

If government were in the hands of a wise and benevolent autocracy a national geological survey would be so conducted as to be useful to the people whose taxes go toward its support, but it would probably be useful in the broader sense that I have outlined. It would give the people not perhaps what they thought they wanted but what, in the wisdom of their government, seemed best for them. I believe that a survey so directed would aim to encourage and promote the study of geology by undertaking those general problems and regional investigations that would be likely to remain untouched if left to private enterprise. It would lay the foundation for the most economical and efficient development of the natural resources of the country by ascertaining and making known the location, character, and extent of the national mineral resources. As an aid to the intelligent utilization of these resources and to the discovery of deposits additional to those already known, it would properly occupy itself with problems concerning the origin and mode of formation of mineral deposits. Last, but not least, it would accept the responsibility, not only for making known the material resources of the country but for contributing to the moral and intellectual life of the Nation and of the world by seeing to it that the country's resources in opportunities for progress in the science of geology are fully utilized. I may illustrate my meaning by examples taken from the

publications of the United States Geological Survey. In my opinion, such work as Dutton's Tertiary History of the Grand Canyon, Gilbert's Lake Bonneville, and the investigations of Marsh, Cope, and their successors on the wonderful series of reptile, bird, and mammal remains found in the Cretaceous and Tertiary strata of the West are fully as adequate and appropriate a return for the expenditure of public funds as a report describing the occurrence of a coal bed and giving the quantity of coal available in a given field. Many years ago when the United States Geological Survey was under heavy fire in Congress one Member of that body in some unexplained way learned that Professor Marsh had discovered and had described in a Government publication a wonderful fossil bird with teeth—a great diver up to 6 feet in length. He held this up to ridicule as a glaring example of the waste of public funds in useless scientific work, quite unaware of the light that this and similar discoveries threw upon the interesting history of the development of birds from reptiles and upon evolution, or of the intellectual value of such a contribution to knowledge. The representative of a people educated in the value of geologic science would, by such an exhibition of ignorance, discredit himself in the eyes of his constituents.

FUNCTIONS IN A DEMOCRACY.

Our Government, however, is not an all-wise benevolent autocracy, but is democratic in plan and intent and suffers from certain well-known disadvantages from which no democracy has yet been free. The wishes of the politically active majority control, and these wishes may or may not coincide with those of the wisest and most enlightened of the citizens. The funds for Government work in science must be granted by Congress, and the vote of each Congressman is determined by the real or supposed desires of his constituents. A national scientific bureau, if it is to survive, must have popular support, and to obtain and hold such support it must do at least some work that the majority of the people can understand or can recognize as being worth the doing. Here evidently compromise with scientific ideals is necessary. Something must be sacrificed in order that something can be done. Such concessions and compromises are inseparable from democratic government, and the scientific man of high ideals who is unable to recognize this fact will inevitably fail as a director of the scientific work of a government bureau. Such a man is likely to insist that no concessions are necessary and that the public will support science which is not interesting to it or from which it can see no immediately resulting material benefit. One very eminent geologist with whom I was once conversing held this view. He said that he had always found that he could go before a legislative body

and secure appropriations for scientific research by being absolutely frank and making no attempt to show that the results of the work would be what the average man would term "useful" within the immediate future. His confidence was possibly well grounded, but I am inclined to think that the success gained by him was rather a tribute to his earnest eloquence and winning personality than a proof that the people are yet ready to contribute their taxes to the support of investigations that, so far as they can see, are neither useful nor interesting.

CHARACTER OF COMPROMISES.

Lest it be supposed that I am advocating the surrender of the high ideals of science to the political business of vote getting, I hasten to point out that surrender and compromise are not synonymous and may be very far apart. Some compromise there must be, but in my opinion the most delicate and critical problem in the direction of a national scientific bureau is to determine the nature and extent of this compromise so as to obtain the largest and steadiest support of real research with the least sacrifice. Complete surrender to popularity may mean large initial support but is sure to be followed by deterioration in the spirit of the organization and in the quality of its work, by loss of scientific prestige, and by final bankruptcy even in that popular favor which had been so sedulously cultivated.

The extent to which concessions must be made will depend largely, of course, upon the general level of intelligence of the people and upon the degree to which the less intelligent are influenced through the press and other channels by those who are able to appreciate the value of science. The more enlightened the people the more general and permanent will be their support of science.

IMPORTANCE OF POPULAR EDUCATION IN GEOLOGY.

This leads us to the consideration of what I believe to be one of the most important of the functions of a government scientific bureau, namely, education. Of all forms of concession, if needed it is really a concession, this is the least objectionable and most fruitful. Its results are constructive and cumulative. It is not, like other concessions to popularity, corrosive of the scientific spirit of an organization, and in so far as it calls for clear thinking and attractive presentation by those who put it into practice, as well as the ability to grasp and expound essentials, its educational effect may be subjective no less than objective. Whatever may be true of those engaged in other sciences, geologists in this country have shown little interest in popularizing their science or in encouraging its pursuit by amateurs. Such attempts as have been made have often been inept and unsuc-

cessful, and other professional geologists have looked with more or less disdain upon those of their fellows who have tried to expound their science to the people. They have felt that men with unusual ability for research should devote all of their energy to the work of enlarging the confines of knowledge rather than to that of disseminating and popularizing what is known to the few. There is undoubtedly much to be said for this view, and when applied to certain exceptional men it is strictly correct. When, however, we think of Darwin and compare the magnitude of his achievements with the pains that he took to make his conclusions comprehensible by the multitude, we are inclined to feel that only by extraordinary ability and performance in certain directions can an investigator in natural science be altogether absolved from the duty of making himself intelligible to more than a few specialists in his own line. There are undoubtedly many scientific men, thoroughly and earnestly convinced of the importance of their researches, who would in the long run be doing more for humanity and perhaps for themselves if they would spare some time to tell us as clearly and attractively as possible what it is that they are doing. While I believe this to be true of scientific men in general, it is particularly true of those who are officially servants of a democracy. A democratic government might almost be characterized as a government by compromise, and this is one of the major compromises that confronts scientific men in the service of such a government. The conclusion that a very important function of a national geological survey is the education of the people in geology and the increasing of popular interest in that science appears to be unavoidable, yet it is surprising how little this function has been recognized and exercised. The results of such education are a direct and permanent gain to science, whereas, on the other hand, the consequence of prostituting the opportunities for scientific work to satisfy this and that popular demand for so-called practical results in any problem that happens to be momentarily in the public eye is a kind of charlatanry that is utterly demoralizing to those who practice it and that must ultimately bring even popular discredit on science. A bureau that follows such a policy can neither hold within it nor attract to its service men animated by the true spirit of investigation.

METHODS OF EDUCATION.

It is not practicable in the present address to discuss in detail the many possibilities of educational work in geology. Only a few general suggestions can be offered.

In the first place the importance of education by a national geological survey should be frankly recognized, and the idea that it is beneath the dignity of a geologist to participate in this func-

tion should be discountenanced. A geological survey should include on its staff one or more men of high ability who are especially gifted in interesting the public in the purposes, methods, and results of geologic work—men of imagination who can see the romance of science; men of broad sympathy who know the hearts and minds of their countrymen from one border to the other; men imbued with the truthful spirit of science; and, finally, men skilled in the art of illuminating the cold, impersonal results of science with a warm glow of human interest.

It should be the duty of these men to see that so far as possible all the results of geologic work are interpreted to the people so that every citizen can benefit to the limit of his individual capacity. Magazines, the daily papers, moving pictures, and all other possible means of publication should be utilized. There should be close contact with educators, and special pains should be taken to prepare material for use in schools and colleges. Carefully planned courses at university summer schools and elsewhere might be given by members of the educational or publicity staff or by certain selected geologists from the field staff.

Geologists in preparing papers and reports should consider with particular care the question, Who may be reached by this? Some scientific results can not be popularized, and papers on these may be written in the concise, accurate language of science. Others, however, may, by taking sufficient care and trouble, be made interesting to more than a small circle of scientific colleagues. Every effort should be made to enlarge this circle by simple and attractive presentation. I am inclined to think that in some cases a geologist might issue separately or as a part of his complete report an abstract or résumé in which all effort is concentrated on an endeavor to be interesting and clear to as many people as possible. If this were done, I am sure that the writer would be in a position to appraise more truly the value of his complete report and might proceed to rewrite some portions of it and to omit others, without loss to science and at a saving in paper and printing.

RELATIONS WITH UNIVERSITIES.

In connection with the subject of education attention may be called to the fundamental importance of establishing and maintaining close and cordial relations between a government scientific bureau and the universities. The advantages of such relations are so many that it is difficult to enumerate them all, but it may be pointed out that any plan of popular education in science will be seriously crippled if the professional teachers, whose influence in molding the thoughts and determining the careers of the young

men and women of the country is so great, are out of sympathy with the government organization that is attempting to quicken the interest of the people in a particular branch of science. Moreover, it is vital to such an organization that it should attract to its service young men of exceptional ability in science. This it is not likely to do if professors of geology feel that they must conscientiously advise their most promising graduates to avoid government service. Doubtless some teachers of geology in the universities fail to realize the necessity for some of the compromises inevitable in a government bureau or in their impatience at some of the stupidities of bureaucratic procedure are inclined to place the blame for these where it does not belong; a few may cherish personal grievances. No class of men is without its unreasonable members, and neither rectitude nor tact can prevent occasional clashes; but if a national geological survey can not command the respect and hearty support of most of the geological faculties of the universities the consequences to the progress of geology must be deplorable. Any approach to such a condition demands immediate action, with less emphasis on the question, "Who is to blame?" for in all probability there may be some fault on both sides, than on "What can be done to restore relations of mutual regard and helpfulness?"

THE AMATEUR IN GEOLOGY.

In the present age of specialization we are apt to forget how much geology owes to amateurs, particularly in Britain and France. Sir Archibald Geikie in the concluding chapter of his *Founders of Geology* dwells particularly on this debt. He says:

In the account which has been presented in this volume of the work of some of the more notable men who have created the science of geology, one or two leading facts stand out prominently before us. In the first place, even in the list of selected names which we have considered, it is remarkable how varied have been the ordinary avocations¹ of these pioneers. The majority have been men engaged in other pursuits, who have devoted their leisure to the cultivation of geological studies. Steno, Guettard, Pallas, Füchsel, and many more were physicians, either led by their medical training to interest themselves in natural history, or not seldom, even from boyhood, so fond of natural history as to choose medicine as their profession because of its affinities with that branch of science. Giraud-Soulavie and Michell were clergymen. Murchison was a retired soldier. Alexandre Brongniart was at first engaged in superintending the porcelain manufactory of Sèvres. Demarest was a hard-worked civil servant who snatched his intervals for geology from the toils of incessant official occupation. William Smith found time for his researches in the midst of all the cares and anxieties of his profession as an engineer and surveyor. Hutton, Hall, DeSaussure, Von Buch, Lyell, and Darwin were men of means, who scorned a life of slothful ease, and dedicated themselves and their fortunes to the study of the history of the earth. Playfair and Cuvier were both teachers

¹ "Vocations" would seem to be the right word here. F. L. R.

of other branches of science, irresistibly drawn into the sphere of geological inquiry and speculation. Of the whole gallery of worthies that have passed before us, a comparatively small proportion could be classed as in the strictest sense professional geologists, such as Werner, Sedgwick, and Logan. Were we to step outside of that gallery, and include the names of all who have helped to lay the foundations of the science, we should find the proportion to be still less.

From the beginning of its career, geology has owed its foundation and its advance to no select and privileged class. It has been open to all who cared to undergo the trials which its successful prosecution demands. And what it has been in the past, it remains to-day. No branch of natural knowledge lies more invitingly open to every student who, loving the fresh face of Nature, is willing to train his faculty of observation in the field and to discipline his mind by the patient correlation of facts and the fearless dissection of theories. To such an inquirer no limit can be set. He may be enabled to rebuild parts of the temple of science, or to add new towers and pinnacles to its superstructure. But even if he should never venture into such ambitious undertakings, he will gain, in the cultivation of geological pursuits, a solace and enjoyment amid the cares of life, which will become to him a source of the purest joy.

In this country at the present time, as Mr. David White, in an as yet unpublished address, has, I believe, pointed out, the amateur geologist is rare, owing partly to the way in which the subject is taught, and few indeed are the contributions made to the science by those who follow geology as an avocation or hobby. This is unfortunate, and an improvement of this condition should be one of the major objects of the educational program of a national geological survey. The science lends itself particularly to pursuit as a recreation by men of trained intellect who must find in the open air some relief from sedentary professions. In a country still so new as ours geologic problems lie on every hand, and many of them can be solved wholly or in part without elaborate apparatus or laboratory facilities. The standards for the professional geologist should be high, but there is no necessity that maintenance of such standards should be accompanied by a patronizing or supercilious attitude toward the work of the amateur. Rather, let the professional geologist cultivate sympathy, tolerance, and generosity toward all who are earnestly seeking for the truth; let him help by encouragement instead of deterring by disdain. There is no better evidence of a wide interest in geology than the existence of numerous amateur workers, and it is decidedly to the advantage of the professional geologist and of the science to encourage in every way possible the efforts of such workers and to increase their number.

KINDS OF WORK TO BE UNDERTAKEN BY A NATIONAL GEOLOGICAL SURVEY.

There has been considerable difference of opinion as to the kinds of work that should be undertaken by a national geological survey.

Shall its field be confined to what may be included under geology or shall it embrace other activities, such as topographic mapping, hydrography and hydraulic engineering, mining engineering, the classification of public lands, the collection and publication of statistics of mineral production, and the mechanical arts of publication such as printing and engraving. These various lines of activity may be divided into two main classes—those that are more or less contributory to or subordinate to the publication of geologic results, and those that have little, if any, connection with geology.

I am one of those who believe that a geological survey should be essentially what its name implies—that it should confine its activity to the science of geology. This opinion is held, however, in full realization of the fact that here, as elsewhere, some compromise may be necessary. This may be dictated by law or may be determined by policy.

The organic law of the United States Geological Survey, for example, includes among the duties of the organization "the classification of the public lands." There may be some difference of opinion as to what the framers of the law meant by this provision, but it is at least a reasonable conclusion that they intended the sort of classification adopted by the General Land Office. If so, the determination of the so-called "mineral" or "nonmineral" character of public lands is undoubtedly a proper function of the United States Geological Survey, although it is one that was neglected by that survey for many years and has not yet received the recognition of a specific appropriation, except recently in connection with the stock-raising and enlarged-homestead acts.

TOPOGRAPHIC MAPPING.

Inasmuch as the preparation of a topographic map is a necessary preliminary to accurate and detailed geologic mapping, a geological survey is vitally interested in seeing that satisfactory maps are available as needed. Whether a particular geological survey should itself undertake this mapping depends upon circumstances. If another Government organization is equipped for doing this work and can provide maps of the requisite quality when needed, it would appear that the Geological Bureau should leave this work to the other organization, particularly as the maps required to keep abreast of geologic requirements are likely to constitute only a part of the work of the topographic bureau. There are certain decided advantages, however, in having the topographic work done by the Geological Survey, and these advantages must be weighed against other considerations. With the topographic and geologic work under a single control, the geologist is more likely to be assured of getting the kind

of map he desires at the time it is needed. Cooperation between geologists and topographers is apt to be both closer and more flexible than it would be if the two staffs were in separate organizations. Finally, the field work in topography and geology is in some respects alike and is carried out by similar methods and equipment. Occasionally the two kinds of work can be combined and carried on simultaneously.

The general question—whether a national geological survey shall do its own topographic mapping—appears to be one that can not be answered once for all but must be determined for each country. In an old country, where accurate and detailed maps have long been made by military and other organizations, a geological survey may be under no necessity of providing its own topographic base maps. In a new country, where exploration is still in progress, the Geological Survey may have to make its own topographic surveys. The main point, as I see it, is that the Geological Survey must have maps of the standard required by it with the least possible delay but should not undertake to make them itself if other organizations that can and will provide the maps needed are already in the field.

STATISTICS OF MINERAL PRODUCTION.

We have seen that there is at least a very close connection between topographic and geologic mapping and that in this connection may lie a sufficient reason why both kinds of work should be undertaken by the same organization. Is there as good a reason why the study of geology and the collection of statistics of mineral production should be united?

When shortly after the organization of the United States Geological Survey the collection of statistics was begun, those geologists who were most influential in urging that the survey should undertake statistical work adduced as the principal reason that the people desired such figures, and if the Geological Survey did the work it would be able to secure larger appropriations than if the task were left for others. It does not appear to have been thought at that time that geologists were the only men who could satisfactorily do statistical work or that it was necessary to impose this task on them. Subsequently, however, the work was apportioned among the geologists. The reasons for this step appear to have been, first, that the results of having the statistical reports prepared under contract by specialists who were not on the regular staff of the organization had proved unsatisfactory; second, that by apportioning the work among the geologists already on the staff not only would the apparent cost in money be less than under the former arrangement, but it would, in a bookkeeping sense, be very much cheaper than taking on new men

for this particular work; finally, it was argued that geologists could apply their knowledge of the field relations of ore deposits to improve the character of statistical reports and would themselves benefit by additional opportunities to visit and examine many deposits that they might not otherwise see.

It is undoubtedly true that the statistical reports of the United States Geological Survey have greatly improved in accuracy, fullness, and general interest since this plan was adopted. It is also true that some geologists have turned their opportunities as statistical experts to good account both in enlarging their experience and by gathering material that has been worked into geological papers. Nevertheless, the policy has, in my opinion, been a mistake both economically and scientifically. It has insidiously filched the time of highly trained men who have shown originality and capacity for geologic research and has tied these men down to comparatively easy and more or less routine tasks. Some geologists who were once scientifically productive no longer contribute anything to geological literature but are immersed in work that men without their special geological training could do as well. To a certain extent the policy is destructive of scientific morale. A young geologist sees that a man who publishes, annually or at shorter periods, reports on the statistics of production of some metal becomes widely known to all interested in that metal and is considered by them as the United States Geological Survey's principal expert on that metal. This easily won recognition, with all that it implies or seems to imply in the way of promotion and of industrial opportunity, must constitute a real temptation so long as a scientific man is expected to contribute his own enthusiastic devotion to science as part payment of his salary. The incidental geological opportunities offered by statistical work are found chiefly in connection with a few of the minor mineral resources, rather than with such industrially dominant commodities as petroleum, iron, or copper, and these opportunities for the individual geologist are soon exhausted and are likely to be purchased at a price far out of proportion to their value. The supposition that geological training is essential for good statistical work in mineral products is a fallacy, and no man who shows promise of making real contributions to geologic science should be placed in such circumstances that he is virtually forced to worship an idol whose head may be of gold and precious stones but whose feet are assuredly of clay. I am emphatically of the opinion that the collection of mineral statistics is not logically a function of a national geological survey. If, however, such a survey is committed to this task by law, by the lack of any other organization to do the work, or by well-considered reasons of policy, then it is even more certain that

the duty should not devolve upon geologists at the expense of their own science but should be cared for by a special staff. Some cooperation between the statistical staff and the geologic staff may be advisable, but the extent of this cooperation should be determined by executives who are fully alive to the necessity of safeguarding geology against encroachments by statistical work.

WATER RESOURCES.

Studies concerned with the occurrence of underground water are of course as much geological as those concerned with the occurrence of petroleum. Investigations of surface waters, however, including stream gauging and the study of water power, come within the field of engineering and have so little connection with geology that it is difficult to see any logical ground for their inclusion within the group of activities belonging properly to a geological survey. In an ideal apportionment of fields of endeavor among the scientific and technical bureaus of a government, stream gauging and estimation of water power would scarcely fall to the national geological survey. As it happens, the United States Geological Survey does perform these functions, and I am not prepared to say that there is not ample legal and practical justification for this adventitious growth on a geological bureau. There has been little or no tendency to draft geologists into hydraulic engineering, and consequently the principal objection urged against the inclusion of statistical work within the sphere of a geological survey does not here apply. Apparently the only practical disadvantages are the introduction of additional complexity into a primarily scientific organization and the consequent danger of the partial submergence of principal and primary functions by those of adventitious character.

It should be pointed out in this connection that certain studies of surface waters, especially those that are concerned with the character and quantity of material carried in suspension and in solution in river waters, have much geological importance. Such studies supply data for estimating the rate of erosion and sedimentation. They are to be regarded, however, rather as an illustration of the way in which geology overlaps other branches of science and utilizes their results than as reason for considering hydraulic engineering as normally a function of a geological survey.

FOREIGN MINERAL RESOURCES.

One of the results of the war was to suggest the advantage to the citizens and Government of the United States of a central source of information concerning the mineral resources of foreign countries. The United States Geological Survey undertook to gather

this information, primarily for the specific purpose of supplying data to the American representatives at the peace conference. As the Director of the Survey states in his fortieth annual report:

Two general purposes were served—first that of obtaining a clear understanding of the relations between our own war needs and the foreign sources of supply from which these needs must or could be met; second, that of obtaining an understanding of the bearing of mineral resources upon the origin and conduct of the war and upon the political and commercial readjustments that would follow the end of hostilities.

This work, of a kind that so far as known has not been previously undertaken by any national geological survey, has been continued with the view that it is important for those who direct American industries to possess as much information as possible concerning those foreign mineral resources upon which they can draw or against which they must compete. The results aimed at are directly practical and are largely obtained by compilation of available published and unpublished material, as it is manifestly impossible to make direct detailed investigations of the mineral resources of all foreign countries. Nevertheless the work appears to fall appropriately within the field of a geological bureau, and if it can be made to furnish the opportunity, hitherto lacking, for geologists in the Government service to make first-hand comparison between our own mineral deposits and those of other lands the experiment will probably bear scientific fruit.

CHEMISTRY AND PHYSICS.

Mineralogy and paleontology are so closely related to geology that there can be no question of the propriety of including the pursuit of these sciences within the scope of a geological survey. The application of chemistry and physics to geological problems admits of more discussion. Chemical work, however, as carried on in connection with geological investigations is of such special character and must be conducted in such intimate contact with geological data as to make it almost certain that better results can be obtained with a special staff and equipment than would be possible were the routine and investigative work in geological chemistry turned over to some central bureau of chemistry. The same argument is believed to be applicable also to physics. Research in geophysics was at one time a recognized function of the United States Geological Survey, but since the founding of the Geophysical Laboratory of the Carnegie Institution of Washington this field has been left almost entirely to that splendid organization, which is unhampered by some of the unfortunate restrictions of a Government bureau. Under these particular and unusual conditions this course may have been wise,

although it does not negative the conclusion that, in general, investigation in geophysics are logically and properly a function of a national geological survey.

SOILS.

The study of soils, with reference to origin, composition, and classification, is unquestionably a branch of geology, but the geologist, with tradition behind him, generally looks upon soil as a nuisance, and geological surveys have reflected his attitude. In the United States the classification and mapping of soil types has for some years been in progress by the Department of Agriculture. While quite devoid of any enthusiasm for engaging in soil mapping, I wish to point out merely that this work, if its results justify its performance by the Government and if the classification adopted is based on chemical, physical, and mineralogical character, rather than on crop adaptability, is properly a function of the national geological survey.

SEISMOLOGY.

Another subject that is comparatively neglected by national geological surveys is seismology. It can scarcely be asserted that earthquakes have no economic bearing, and conspicuous or destructive examples usually receive some official attention—after the event. The comparative neglect of systematic study of earthquakes is probably due to a number of causes. One of these is that few geologists specialize in seismology—a science in which little progress can be made unless the investigator possesses unusual qualifications in mathematics and physics. Another reason, probably, is that to most men the difficulties in the way of gaining real knowledge of the causes of earthquakes, and especially of predicting with any certainty the time, place, intensity, and effects of earthquakes appear rather appalling. Finally, earthquake prediction, or even the recognition of the possibility of future earthquakes in a particular part of the country, is likely to have consequences decidedly unpleasant to those responsible for the prediction. Experience in California has shown that a community still staggering from a violent shaking may insist with some acerbity that nothing of any consequence has happened and that it never felt better in its life.

Notwithstanding these difficulties, I believe that a national geological survey, in a country where serious earthquakes have taken place and may occur again, should consider the collection and interpretation of seismological data as part of its duty. Such work is regional in scope and can not be carried far by local initiative and by individual investigators on their own resources. In spite of diffi-

culties, I believe that it is within the range of possibility that some day we shall be able to predict earthquakes with sufficient reliability to give the prediction practical utility.

SUMMARY.

Briefly summarizing what has gone before, I conclude that the chief primary function of a geological survey is geological research and that the spirit of investigation should be the same whether the work is undertaken to increase knowledge and to serve as the starting point for further attacks on the unknown or is begun with a definite economic or practical result as its desired goal. Compromise and concession are inevitable, but the necessity for making them should not and need not permit the real purpose of the organization to sink from sight. If the members of a scientific bureau can confidently feel that those charged with its direction make such concessions wisely with the higher purposes of the bureau really at heart, their whole attitude towards their work will be entirely different from that into which they will fall if they become convinced that scientific ideals receive only perfunctory regard and that the real allegiance is directed elsewhere.

What may be called the chief secondary function of a national geological survey is believed to be popular education in geology, both for the benefit of the people and as providing the most enduring basis for the support of such an organization by a democracy. Such education should be conducted through every possible channel and in close cooperation with all the educational institutions of the country. One of its objects should be the revival and encouragement of amateur geological observation and study. In this connection I heartily approve the present trend in the policy of the American Association for the Advancement of Science and believe that this great organization will fulfill its purpose and advance science much more effectively than at present if it will leave to the various special scientific societies the holding of meetings devoted to the presentation of scientific papers, and apply itself to the popularization of science and to the encouragement of cooperation between different branches of science.

PERSONNEL.

Finally, a few words may be said concerning the relation between the personnel of a geological survey and the results obtained by the organization. If such a survey is to attract to its service men of first-rate ability and to hold these men after their development and experience have made them of the highest value, certain inducements must be offered. Salary is unfortunately the first of these that comes to

mind under conditions that continually force the scientific men in Government service to recognize painfully how inadequate at present is the stipend upon which he had existed before the war. It is all very well to insist that the scientific man does not work for money and should not trouble his thoughts with such an unworthy consideration. Nevertheless if he is to do the best of which he is capable, he must be lifted above the grind of poverty, be able to give his children those educational advantages that he can so well appreciate, have opportunity for mental cultivation, and feel his social position to be such that he can mingle without humiliation with his intellectual peers. If it is destructive to the scientific spirit to set up material gain as an object, it may be equally blighting to scientific achievement to force the attention continually downward to the problem of meager existence. The normal scientific man usually has other human beings dependent upon him, and the traditional spirit of self-sacrifice and the indifference to material reward that are commonly attributed to the true investigator may, when these members of his family are considered, come very close to selfishness.

However, salary, important as it is, is by no means the only determinant. If it is reasonably adequate, most men who are animated by the spirit of science will find additional reward in their work itself if this is felt to be worthy of their best efforts. A man of first-rate scientific ability, however, will not enter an organization in which consecutive application to a problem is thwarted, in which he is expected to turn to this or that comparatively unimportant task as political expediency may dictate, or in which the general atmosphere is unfavorable to the initiation and prosecution of research problems of any magnitude. If a man of the type in mind finds himself in such an uncongenial environment, he is likely to go elsewhere. The final effect upon the organization will be that its scientific staff will be mediocre or worse and it will become chiefly a statistical and engineering bureau from which leadership in geology will have departed.

If, on the other hand, a young geologist can feel that every possible opportunity and encouragement will be given to him in advancing the science of geology; that results on the whole will be considered more important than adherence to a schedule; that imagination and originality will be more highly valued than routine efficiency or mere executive capacity; that he will not be diverted to tasks for which, important as they may be, his training and inclination do not particularly fit him; that those who direct the organization are interested in his development and will give him all possible opportunity to demonstrate his power of growth; and that appreciation and material reward will be in proportion to his scientific achieve-

ment, he will then be capable of the best that is in him and will cheerfully contribute that best to the credit of the organization that he serves.

A national geological survey should hold recognized leadership in geology in the country to which it belongs, and attainment of this proud position must obviously depend upon the quality of its geological personnel. With respect to personnel, at least three conditions may be recognized—first, that in which the ablest geologists in the country are drawn to and remain in service; second, that in which geologists perhaps of a somewhat lower grade as regards scientific promise are attracted to the service for a few years of training and then pass out to positions where the opportunities for research or for increased earnings are greater; and, third, that in which able young men no longer look upon the geological survey as a desirable stepping-stone to a future career. Who can doubt that it is the first condition that raises an organization to pre-eminence in science and the last that marks opportunities lost or unattained? Those responsible for the success of a geological survey, if they be wise, will watch the trend of the organization with reference to these conditions much as the mariner watches his barometer and, like him, if the indication be threatening, take action to forestall disaster.

THE INFLUENCE OF COLD IN STIMULATING THE GROWTH OF PLANTS.¹

By FREDERICK V. COVILLE,
Botanist, United States Department of Agriculture.

[With 27 plates.]

In regions having a cold winter like ours, with prolonged or repeated freezing, the native trees and shrubs become dormant in autumn. According to the general belief this condition is brought about by the cold. It is also the general belief that warm weather is of itself the sufficient cause of the beginning of new growth in spring. Both these ideas are erroneous. It is the object of the present address to show, first, that in our native trees and shrubs dormancy sets in before cold weather, and that cold weather is not necessary for the establishment of complete dormancy; second, that after such dormancy has begun, the exposure of the plants to an ordinary growing temperature does not suffice to start them into growth; third, that these plants will not resume normal growth in the warm weather of spring unless they have been subjected previously to a period of chilling; and, finally, a theory will be advanced to explain this paradoxical effect of cold in stimulating growth instead of retarding it.

The subject will be presented in a series of numbered statements, each followed by supporting evidence.

1. Trees and shrubs of cold climates become dormant at the end of the growing season without the necessity of exposure to cold weather.

A little more than 10 years ago, while engaged in a series of greenhouse experiments, the writer came upon a strange phenomenon which was wholly unexpected and which threatened to interfere seriously with the success of the experiments. Healthy blueberry plants, intended to be used during the winter for breeding purposes, were brought into the greenhouse at the end of summer and were kept at an ordinary growing temperature. They refused to continue their growth during the autumn, gradually dropped their leaves, and

¹Address delivered Apr. 27, 1920, before the National Academy of Sciences. Reprinted from the *Journal of Agricultural Research*, vol. 20, pp. 151 to 160, 1920.

went into a condition of complete dormancy. They did this at a greenhouse temperature which in spring and summer would have kept the plants in a condition of luxuriant growth. The completeness of the condition of dormancy which such plants reach can be best appreciated from photographs. (See pl. 1.)

Since 1910 this experiment has been repeated many times, and with many species of plants, and without exception those trees and shrubs native of our northern cold-winter region which were tested went dormant in fall or winter regardless of temperature. In comparing outdoor plants with indoor plants of the same species the most that can be said in favor of outdoor conditions is that dormancy progresses a little faster in outdoor plants, evidently because their foliage is injured by freezing weather, and they drop their leaves somewhat earlier than indoor plants.

2. Trees and shrubs that are kept continuously warm during the winter start into growth much later in spring than those that have been subjected to a period of chilling.

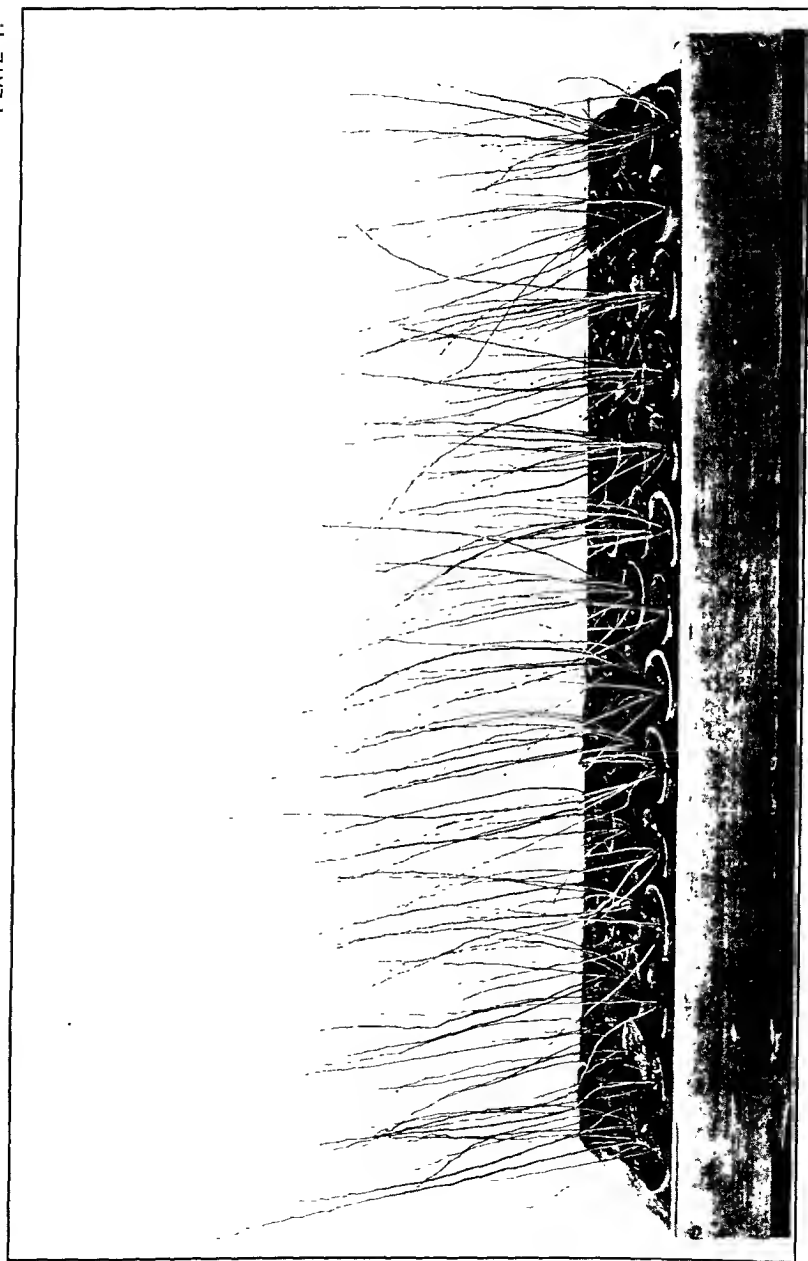
In the late winter and early spring of 1910 I waited patiently, and then impatiently, for my indoor plants to bloom, and at last I was forced to realize that they never would bloom. When compared with plants of the same kind that had been outdoors during the winter and had been brought into the greenhouse in early spring, the difference was astonishing. The outdoor plants burst into leaf and flower luxuriantly, while the indoor plants remained completely dormant and naked. The experiment was repeated many times and with various species of plants, some of which may be used in illustration. (See pls. 2 to 5.)

At first it was supposed that the plants needed to be frozen to start them into growth, but a single freezing proved not to be effective. And then it was found that the dormant plants would start into growth without any freezing whatever. It was necessary only that they be subjected to a period of prolonged chilling, usually two to three months, at a temperature a few degrees above freezing.

If plants are kept continuously in a warm place without chilling, the dormant condition often continues for an extraordinary length of time. In some instances plants have remained dormant for a whole year under conditions of heat, light, and moisture that ordinarily would make the same plant grow with the greatest luxuriance.

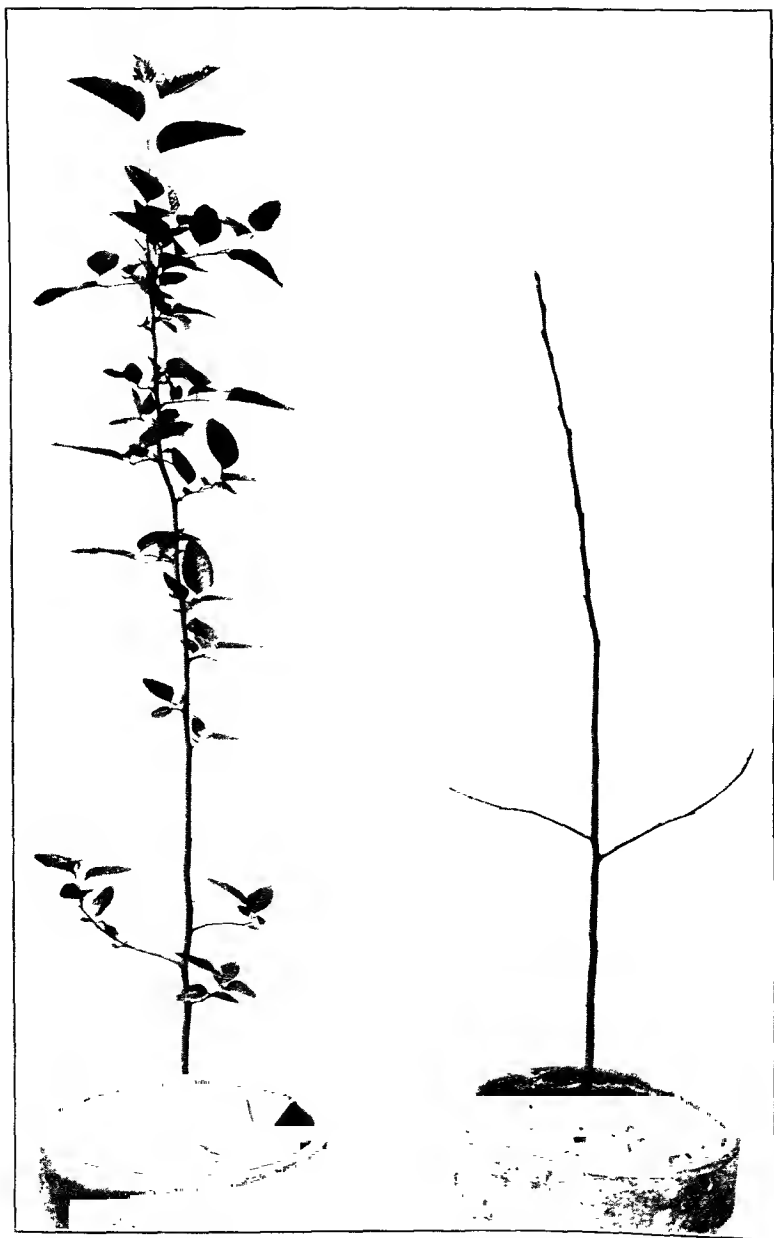
3. The stimulating effect of cold is limited to such portions of the plant as are subjected to the chilling.

The conspicuous difference in spring growth between chilled plants and plants not chilled has already been shown. These differences, furthermore, can be produced experimentally upon different parts



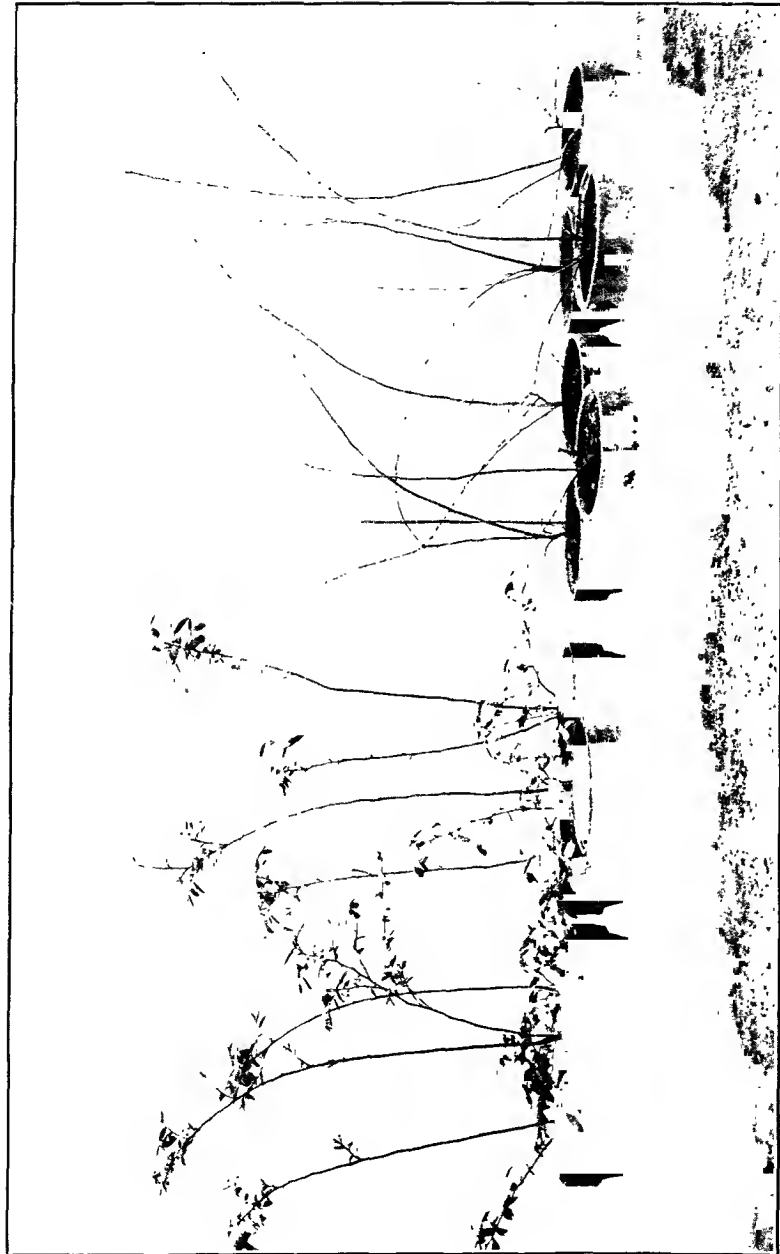
BLUEBERRY PLANTS, *VACCINIUM CORYMBOSUM*, MADE DORMANT WITHOUT COLD.

These blueberry seedlings, in 2-inch pots, were kept during the fall and winter in a greenhouse at a temperature of 55° to 70° F. Although this is a very favorable temperature for the growth of the blueberry, these plants shed their leaves and became completely dormant, just as they ordinarily do when exposed to the frost and cold of an outdoor fall and winter. The photograph was taken on January 25.



CHILLED AND UNCHILLED PLANTS OF WILD CRAB, *MALUS CORONARIA*.

The plant at the left had been outdoors during the fall and winter, leafless and dormant, exposed to the frost and cold. The plant at the right had been in the warm greenhouse during the fall and winter at a temperature of 55° to 70° F. and became, like the other, leafless and dormant. When the outdoor, chilled plant was brought in to the greenhouse in the early spring it promptly began to put out new leaves and twigs, as shown at the left, but the indoor, unchilled plant continued its dormancy, as shown at the right. The photograph was taken April 24, 1917. (One-fifth natural size.)



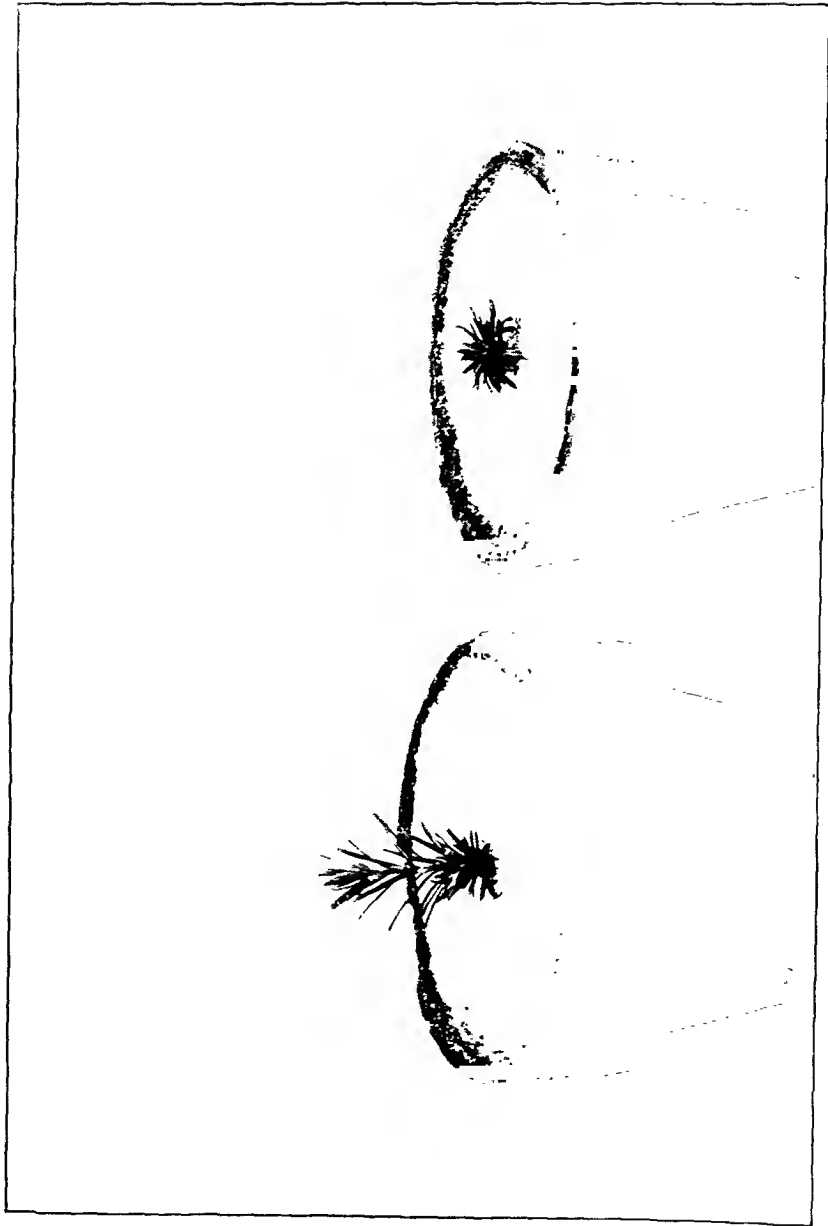
CHILLED AND UNCHILLED BLUEBERRY PLANTS.

The six blueberry plants at the left, after an outdoor winter chilling, were brought indoors on March 25 into a greenhouse having a temperature of 55° to 70° F. and were repotted. On April 20, when the photograph was taken, they had developed both leaves and flowers, while the six plants at the right, which had been in the same greenhouse at 55° to 70° F. all the fall and winter, and were repotted on the same date as the others, were still completely dormant. (One-eighth natural size.)



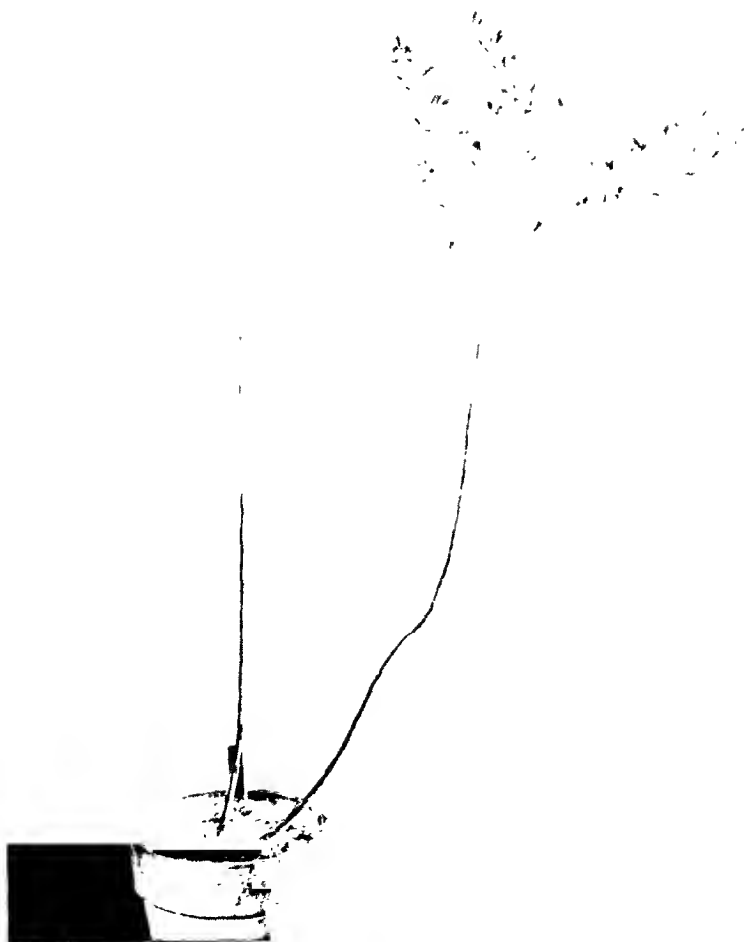
CHILLED AND UNCHILLED PLANTS OF GROUSEBERRY, *VIBURNUM AMERICANUM*.

The illustration shows two one-year-old seedlings with the same history, except that the one at the right was kept during the winter in a warm greenhouse at a temperature of 55° to 70° F., while the one at the left was wintered in a cold greenhouse at a temperature of 32° to 40° F. When spring temperatures warmed up this coldhouse the plants in it began to grow and on April 7, 1914, when the photograph was taken, they had reached the stage shown in the left-hand figure, while the plants in the warmhouse, as illustrated by the right-hand figure, were still completely dormant. (Natural size.)



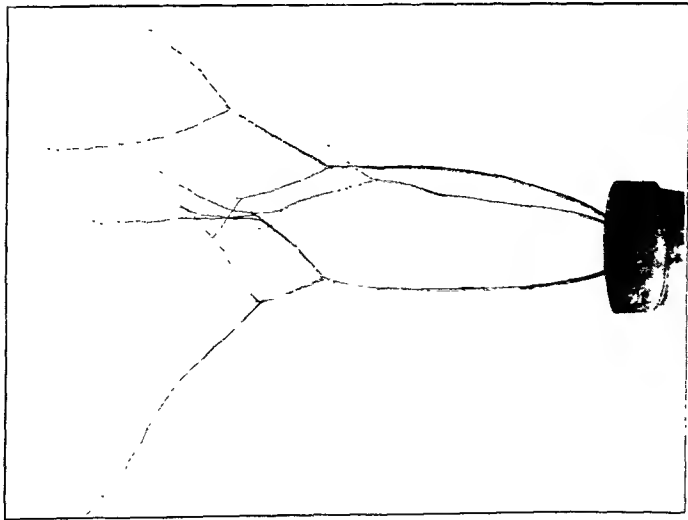
CHILLED AND UNCHILLED PLANTS OF TAMARACK, *LARIX LARICINA*.

These two seedlings, grown from seed procured in Alaska, have had the same history except that the one at the left was wintered in a cold greenhouse at a temperature of 32° to 40° F., the one at the right in a warm greenhouse at a temperature of 55° to 70° F. When the photograph was taken, on April 10, 1914, the chilled plant had put out new growth in the warm spring weather, while the unchilled plant still showed only its leaves of the year before. (Natural size.)



BLUEBERRY PLANT WITH ONE BRANCH STIMULATED TO GROWTH BY COLD.

The right-hand branch has been stimulated to growth by chilling; the left-hand branch has been kept dormant by heat. For a detailed description of this experiment see page 283. (One-seventh natural size.)



BLUEBERRY PLANT WITH ONE BRANCH KEPT DORMANT BY HEAT.

This illustration shows a modification of the experiment illustrated in Plate 6. At the left is shown a dormant indoor blueberry plant, in a 7-inch pot, as it appeared on February 15, 1912. On that date the pot containing the plant was placed on a shelf outside a greenhouse and a single branch was passed through the glass wall into the warm interior. When Spring came the two outside branches, which had been chilled, burst into normal leaf, as shown in the right-hand figure, while the branch inside the greenhouse, which had been kept warm, still remained dormant. The second photograph was made May 21.

of the same plant. Plants thus treated present a very curious and remarkable appearance, as shown in plates 6 and 7.

On February 3, 1912, a blueberry plant (pl. 6) 44 inches in height, which had shed its leaves and become dormant in a warm greenhouse, maintained at a temperature of 60° to 70° F., was subjected to the following experiment: It was repotted in a 7-inch pot and set in the south end of a greenhouse at the temperature already mentioned. A small opening was made in the glass, and through this opening was pushed one of the two stems of the plant. The open space about the stem where it passed through the glass was carefully plugged with moss. During the rest of the winter the plant remained in the same position, the pot and the stem shown at the left in the illustration continuing in the warm temperature of the greenhouse, while the stem at the right, projecting through the glass, was exposed to the rigors of winter, with its alternate freezing and thawing. The illustration, from a photograph made April 18, shows that when spring came the outdoor branch started into normal growth while the indoor branch continued dormant.

A second illustration (pl. 7) shows a modification of the first experiment. In this case the plant was set on a shelf outside the greenhouse and a single branch was passed through the glass wall into the warm interior. When spring came it was this interior branch that remained dormant, all the outside branches putting out leaves promptly and normally.

From a comparison of the two experiments it is evident that the difference in behavior of the indoor and outdoor branches could not have been caused by any special action of the root system, for in one experiment the roots were inside, in the other outside. It is clear that the causes that stimulated growth in the exposed stems operated in the stem itself, not in the roots. This principle is still further exemplified and confirmed by the behavior of cuttings taken from blueberry plants in the first stages of their dormancy. Such cuttings if kept warm continue their dormancy into late spring or summer, but if chilled for two or three months they start into growth at the normal time in early spring.

It should be stated here that the difference in the amount of light inside and outside the greenhouse had nothing to do with the stimulation to growth, for chilled plants are ready to start into growth promptly whether the chilling is done in the full light of an outdoor situation, or in the partial light of a greenhouse, or in the complete darkness of an ordinary refrigerator.

4. *The stimulating effect produced on dormant plants by cold is intimately associated with the transformation of stored starch into sugar.*

In most of our wild species of trees and shrubs the reserve carbohydrate material is stored away during summer and autumn in the form of starch. At the beginning of dormancy the twigs and sapwood are gorged with this material, the starch grains being stored ordinarily in the cells of the medullary rays and sometimes in the pith. As the process of chilling goes on, this starch little by little is transformed into sugar. The presence of large quantities of starch in the fall and early winter may be observed by applying to freshly-cut surfaces of the twigs the well-known starch test of a 2 per cent solution of iodine in a 1 per cent solution of iodide of potassium. With a strong hand lens the starch is readily observed, if present, by the deep blue color it assumes under this treatment. The intensity of the coloration gives roughly an idea of the number of starch grains present, and thus by this simple means anyone may observe in the twigs of trees and shrubs the gradual disappearance of their starch as spring approaches.

The measurement of the increasing amount of sugar is more difficult and must be done by chemical analysis. Through the courtesy of the Chief of the Bureau of Chemistry exact data can be presented on this point from analyses by Mr. Lorin H. Bailey. In samples of dormant blueberry wood, taken in early spring when growth was about to begin, the ratio of sugar to starch proved to be seven times what it was in similar dormant wood taken in autumn.

I desire at this time to comment on the fact that one of my colleagues reading the manuscript outline of this address criticized the use of the word "stimulate" as applied to the effect which chilling produces on these dormant plants. His idea was that the chilling induced certain physiological changes in the cell contents, but that the actual stimulation to growth came from the temperatures that followed the chilling. I defend, however, the propriety of the language I have used, for although the later stages of growth admittedly can not take place without warm temperatures, not only does the transformation from starch to sugar take place at the chilling temperature, but the buds actually swell and push if the chilling temperature is continued for several months. In illustration I may cite the following experiments:

On March 3, 1915, 286 cuttings were made from dormant outdoor blueberry plants. They were stored in bundles, some in moist sphagnum moss, others in moist birch sawdust, at a contemplated temperature of 31° F., just below freezing. The cuttings remained in cold storage until December 6, a little more than nine months. An examination of the cuttings on that date showed that with the exception of a small number which were mildewed and dead one or more buds had begun to swell on every cutting. In other words,



BLUEBERRY CUTTINGS STARTING TO GROW AT 36° F.

These cuttings were placed in cold storage while still completely dormant. Although the temperature did not go above 36° F., buds on each of the cuttings finally began to push, as shown in the illustration. It is to be noted that although growth took place in the buds the other kind of growth, which results in the formation of a callus, or healing-over tissue, at the severed base of the cutting, is wholly lacking. Callusing can not take place at so low a temperature. (Natural size.)



BLUEBERRY PLANT GROWING IN THE DARK AT 36° F.

This plant was in cold storage in the dark in a commercial refrigerating establishment from March 30 to December 4, 1915. The temperature ranged from 33° to 36° F. The new growth made under these conditions appears in the illustration as white shoots with very small unexpanded yellow leaves. Some of the plants in this experiment made new growth to the length of 82 mm. (Natural size.)

growth had already begun to take place at the cold-storage temperature. The thermograph record for the 278 days was as follows:

	Hours.
29° to 32° F.-----	5, 591
32° to 33°-----	990
33° to 34°-----	91

The temperature record did not go above 34°. It is an astonishing fact that temperatures so very near freezing will start dormant plants into growth.

On March 3, 1915, 58 cuttings from dormant outdoor blueberry plants were placed in moist birch sawdust in commercial cold storage at 33° to 36° F. On December 4, nine months later, buds on every cutting had begun to grow. Not one of these cuttings gave a starch reaction when tested with iodine. The transformation of their stored starch into sugar was complete. (See pls. 8 and 9.)

5. The theory advanced in explanation of the formation of sugar during the process of chilling is that the starch grains stored in the cells of the plant are at first separated by the living and active cell membranes from the enzyme that would transform the starch into sugar, but when the plant is chilled the vital activity of the cell membrane is weakened so that the enzyme "leaks" through it, comes in contact with the starch, and turns it into sugar.

I have stated the theory in these words out of regard for simplicity and general understanding, but if anyone should require that it be presented in orthodox technical language it might be restated as follows. The reserve amylum carbohydrate bodies are isolated from the amylolytic enzyme by semipermeable protoplasmic living membranes of high osmotic efficiency, but under the influence of low temperatures the protoplasmic membranes are proximately devitalized, they become permeable to the amylolytic enzyme, and amylolysis ensues. I may add, however, that the use of such terminology seems to me to involve a certain degree of unnecessary cruelty.

From the evidence already presented no one, presumably, will question that the chilling of dormant trees and shrubs is followed by growth and that the growth is associated with the transformation of starch into sugar. But the hypothesis that this transformation is brought about by the weakening of the cell membrane and the consequent leakage of starch-transforming enzymes into the starch chambers may very properly be challenged. In the Tropics there is no chilling weather, yet trees and shrubs spring into growth after the dormant period of the dry season, just as they do in temperate climates after the dormant period of winter. The critical scientific man will therefore ask: Are there not other agencies than chilling which will start dormant trees and shrubs into growth even

in our latitude? It must be said in reply that there are. And it will be worth while to consider some of these causes, for not only are they of interest in themselves but also, instead of weakening the hypothesis here presented, they serve to strengthen and confirm it.

The data may best be presented through a series of illustrations.

The pruning of a long-dormant plant will often start it into growth. (See pl. 10.)

Girdling produces a similar result. (See pl. 11, fig. 1.)

Notching the stem does the same. (See pl. 11, fig. 2.)

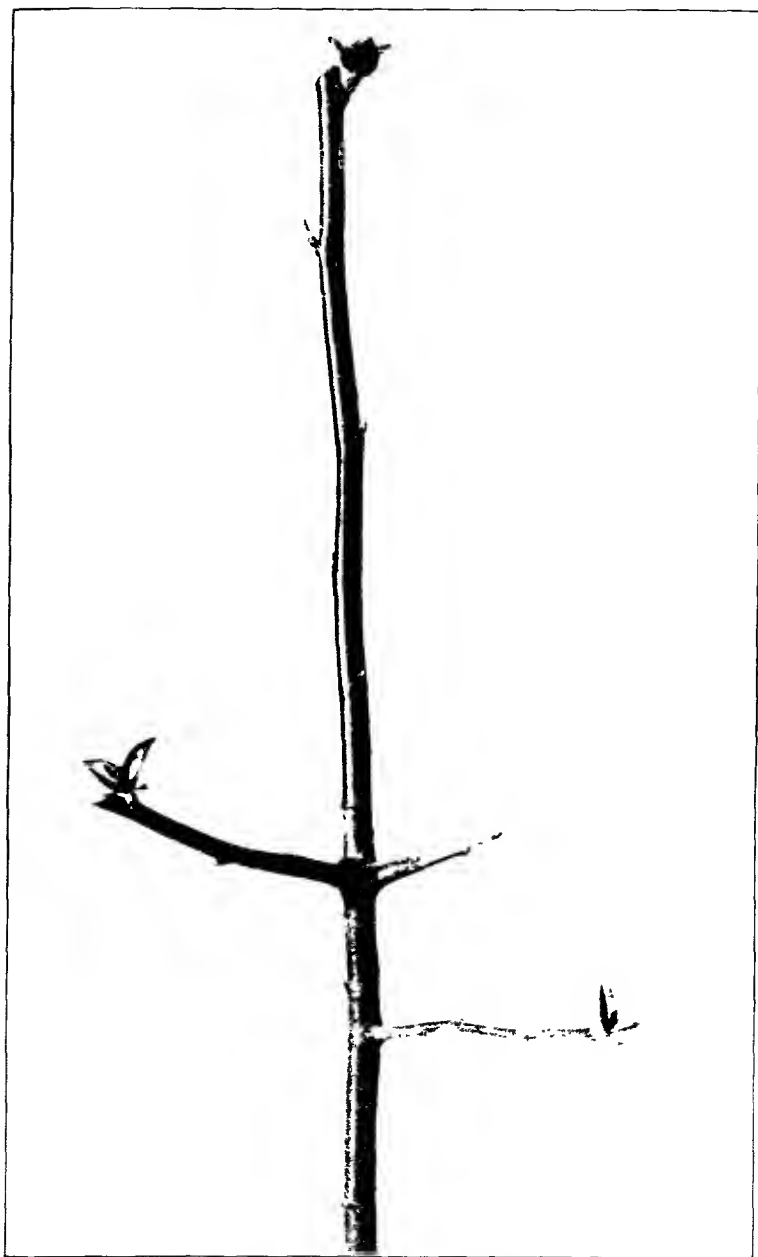
Rubbing the stem also starts the plant into growth. (See pls. 12 and 13.)

In all these examples of the stimulation of growth by injury it is conceived that the enzyme is brought into contact with the starch as a direct result of the breaking and straining of the cells. Sugar is then formed and growth begins.

It should be observed that when a normal chilled plant starts growing it grows from many buds (pl. 14), for the effect of the chilling on sugar formation is general. When a dormant plant starts growing as the result of injury, however, it usually starts, as shown in several illustrations already presented, from a single bud, the one nearest the point of injury. The injury is local and both the sugar formation and the growth that follows it are local.

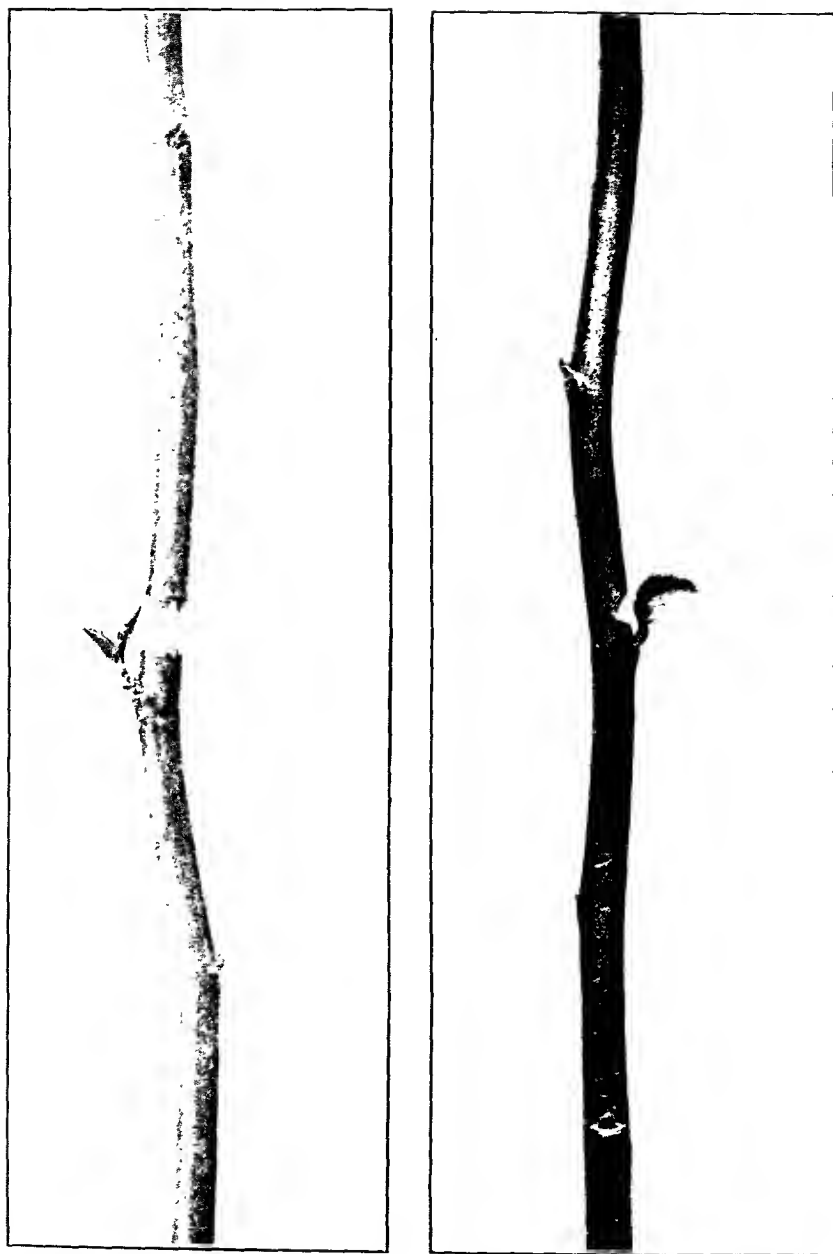
We are now brought to the consideration of a phenomenon which I take to be of special significance, namely, the procedure by which the dormant plant starts itself into growth in the absence of chilling. After a blueberry plant has remained dormant at a warm temperature for a very long period, sometimes a whole year, the tips of the naked branches begin to lose their vitality. Just before or just after the death of the tip a single bud, or sometimes two buds, situated next below the dead or dying part starts growing. (See pls. 15 and 16.) The new growth of the stem is confined to the one or two buds, just as was found to be the case with growth induced by injury. My interpretation of the phenomenon is that as death approaches the cell membranes become weakened in much the same way as when chilled, the enzyme passes through into the starch storage cells, sugar is formed, and the adjacent bud begins to grow. The process going forward here in a restricted portion of the stem, and due to a local cause, is essentially the same as that taking place generally over the plant from a general cause when the plant is chilled.

In the Tropics some plants are able to grow continuously, others become dormant in the dry season and start into growth again at the coming of the rainy season. Tropical plants probably have various methods of coming out of their dormancy, and there is every reason



DORMANT WILD CRAB STIMULATED TO GROWTH BY PRUNING.

This plant had remained dormant in the warm greenhouse during the cold winter at a temperature of 55° to 70° F. On April 5 three branches were pruned, and on April 24, when the photograph was taken, the uppermost bud on each of the pruned branches had begun to grow. On other, unpruned plants no bud growth had taken place. (Two-thirds natural size.)



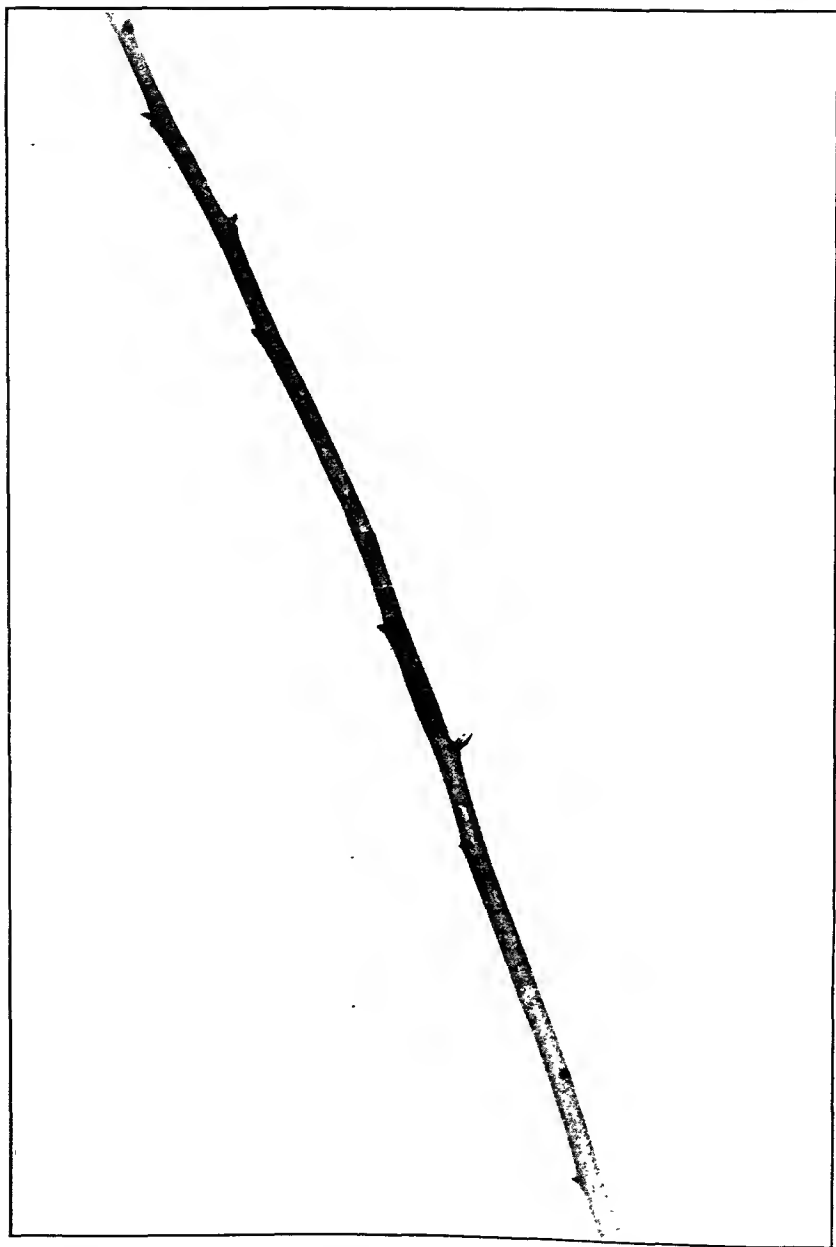
DORMANT WILD CRABS STIMULATED TO GROWTH BY GIRDLING AND BY NOTCHING THE STEM.

These plants had had the same preliminary treatment as the one illustrated in Plate 10, that is, they had been kept in the warm greenhouse all winter, without chilling, dormant and leafless. On April 4 a ring of bark was removed from the plant shown in the left-hand figure, and the soft cambium was carefully scraped away down to the hard wood. On April 21, when the photograph was made, the bud next below the girdle had begun to push. In the case of the right-hand plant the stem was notched in early April. The bud next below the notch soon began to grow, and the photograph was taken on May 2. (Natural size.)



DORMANT BLUEBERRY BUDS STIMULATED TO GROWTH BY CHALKING THE STEM.

This plant was brought into the greenhouse February 4, 1913, to be used in breeding experiments. It flowered, but having been insufficiently chilled, only a few of the uppermost leaf buds on each stem grew. In order to keep small ants from crawling up the stems and interfering with the pollination experiments, the stems were chalked near the middle. The dormant buds in and just below the chalked area started growing. The photograph was taken April 5, the stems being rechalked over the same areas that were originally chalked. After numerous repetitions of the experiment it was found that if the chalking was done lightly the buds would not grow, but if the stems were rubbed hard in the process of chalking, as commonly happened in the case of very smooth stems, the buds grew. It was the hard rubbing, not the chalk, that stimulated the growth. (Natural-size)



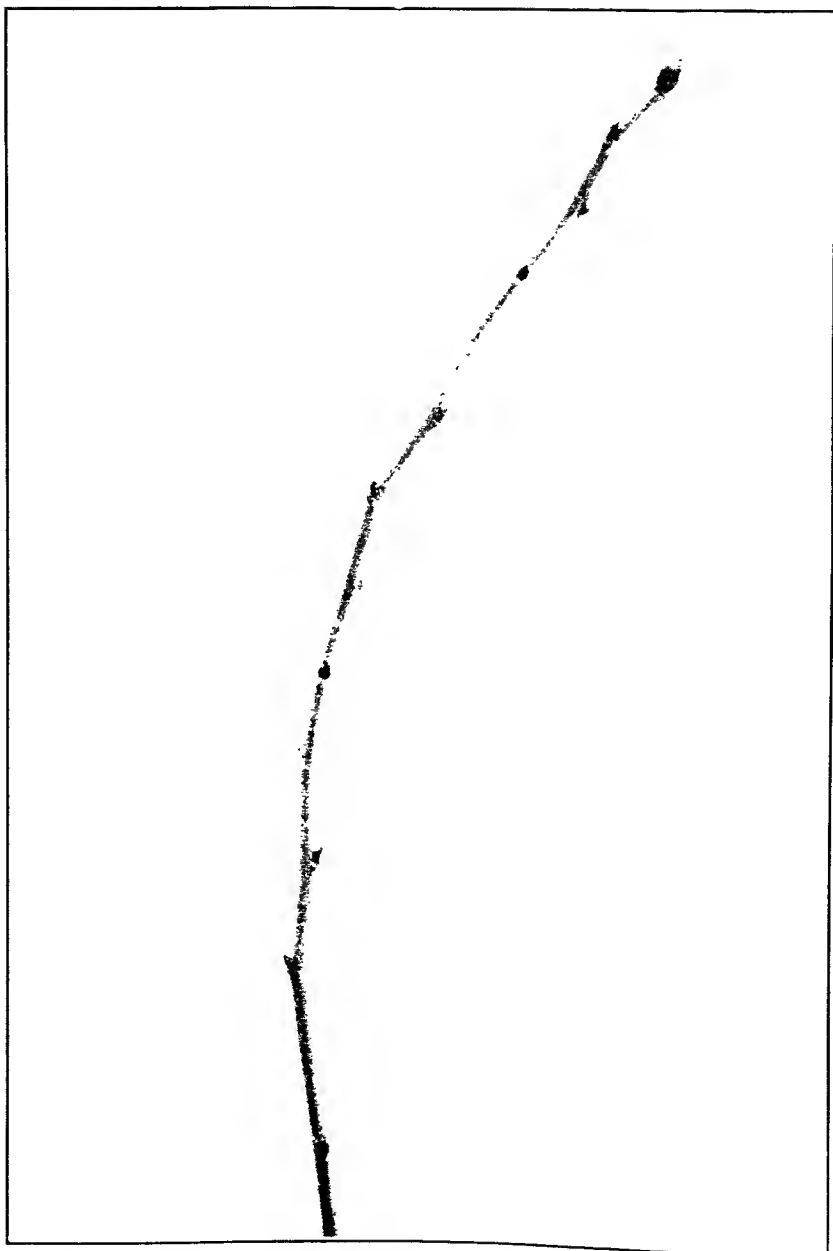
DORMANT BLUEBERRY BUD STIMULATED TO GROWTH BY RUBBING THE STEM.

The photograph, which was taken June 14, 1913, shows a single bud starting into growth on a dormant blueberry plant. The dark area just above the bud is a brown band on an otherwise green stem. It shows the position of a rubbing that was given the stem with a smooth knife handle a few weeks earlier. This bud afterwards grew into a long vigorous branch, while all the other buds remained dormant. (Natural size)



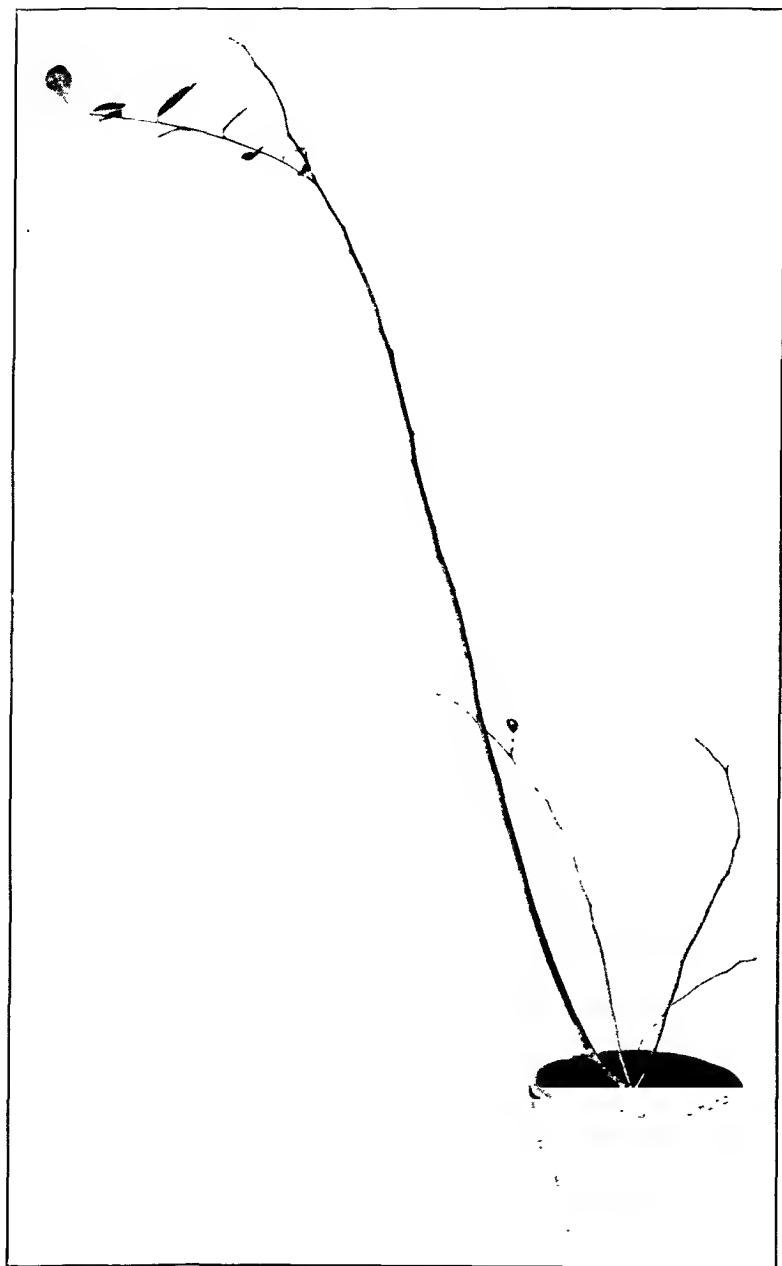
NORMAL SPRING GROWTH ON A BLUEBERRY STEM.

This illustration is from a photograph taken April 21, 1909. In the preceding season the plant had sent up an unbranched shoot. After an outdoor chilling through the winter and early spring it put out flowers and new twigs, as shown in the illustration. The fact to be especially noted is that the new growth on this stem took place from numerous buds. (Natural size.)



ABNORMAL SPRING GROWTH ON A BLUEBERRY STEM, DUE TO LACK OF CHILLING.

This photograph was taken on May 19, 1913. Growth is taking place from only one bud, the third from the tip. The uppermost bud is a flowering bud, the second a leaf bud. Both are dead or dying. This plant has stood in the warm greenhouse all winter and spring. If it had had the usual two or three months of chilling, its starch would have been transformed into sugar and the stem would have flowered and put out new twig growth from numerous buds in the same manner as the stem shown in Plate 14. (Natural size)

**ABNORMAL GROWTH OF AN UNCHILLED BLUEBERRY PLANT.**

This plant became dormant in the autumn in a warm greenhouse, and not being chilled it continued its dormancy through spring and summer for a period of nine months. Then three of its stems began to die at the tips and, following this, growth began to take place from a single bud next below the dying tip on each stem, as shown in the illustration. For the explanation of this abnormal activity see page 286. The photograph was taken October 12, 1916. (Half natural size.)



BLUEBERRY LEAF EXUDING SUGAR FROM GLANDS INTERPRETED AS OSMOTIC-PRESSURE SAFETY VALVES.

This is a leaf of the high-bush blueberry, *Vaccinium corymbosum*. The photograph was taken May 19, 1916, and is enlarged four diameters. The sugar-secreting glands, sometimes called extrafloral nectaries, are situated in this plant on the back of the midrib and along the margins of the leaf, toward its base. The sugar is secreted away from the glands on the left-hand margin and from the second and fourth lateral veins above the sugar drop shown. The drop of sugar is interpreted as a means of relief from excessive internal pressure that might burst the cells of the plant or derange its physiological activities.

to expect that some of them will be found to accomplish this act in the same way as our long-dormant greenhouse plants, by the weakening of their cell membranes. This, I have endeavored to show, is in its effect substantially identical with chilling.

6. *The twigs of trees and shrubs after their winter chilling and the transformation of their starch into sugar may be regarded as mechanisms for the development of high osmotic pressures which start the plant into growth.*

Food in the form of starch can not be utilized by a plant directly. The starch must be changed into sugar before it can be used in making new growth. But this transformation does more than make the starch available as food for the growing plant. It serves also to increase the tendency of the cells to swell and enlarge. In the form of starch the material is inert in the creation of osmotic pressures, but when transformed into sugar it becomes exceedingly active. According to the rigid experimental tests of H. N. Morse and his associates, a normal solution of cane sugar at 32° F. has an osmotic power of 25 atmospheres of pressure. It has been demonstrated that there sometimes occur in the cells of plants osmotic pressures as high as 30 atmospheres, or 450 pounds to the square inch, a pressure sufficient to blow the cylinder head off an ordinary steam engine. It can hardly be questioned that these or even much lower osmotic pressures take an important part in forcing open the buds of once dormant plants.

We have evidence that there sometimes arise within the plant osmotic pressures of such intensity as to threaten the rupture of the cells. Consider the case of the exudation of drops of sugar solution from certain specialized glands. When this exudate of sugar occurs in flowers it is known as nectar and it serves a useful purpose to the plant by attracting sugar-loving insects which unconsciously carry pollen from flower to flower and accomplish the beneficial act of cross-pollination. But sugar solution is often exuded outside the flower, in positions, or at times, that preclude any relation to cross-pollination. For example, a blueberry plant during its spring growth, when a leaf has reached nearly full size, is sometimes observed to exude drops of sugar solution from certain glands on the margins of the leaf and on the back of the mid-rib. (See pl. 17.) It is physically impossible that the sugar has left the cells by osmosis. The sugar serves no useful purpose to the plant through the attraction of insects. The exudate certainly can not represent the elimination of a waste product, for sugar is one of the substances most used by plants in forming new tissues. I can conceive of no reason why the plant should exude sugar except to relieve a dangerous physiological condition, namely, the development of excessive osmotic pressures which would burst the cells of the plant or in some other

way derange its physiological activities. I look upon such sugar glands as safety valves for the relief of excessive osmotic pressures that are dangerous to the internal economy of the plant. And not only is this conception applicable to extrafloral nectaries in general, but it may serve also, in the case of floral nectaries, to explain their origin. Having once arisen as osmotic safety valves, the usefulness of the floral nectaries as an aid to cross-pollination would tend strongly to bring about their natural selection and perpetuation.

7. The establishment of a dormant condition before the advent of freezing weather and the continuation of this dormancy through warm periods in late fall and early winter are protective adaptations of vital necessity to the native trees and shrubs.

A little consideration will show how important the principle of chilling is to those species of trees and shrubs which are subjected each year to several months of freezing weather. If they were so constituted as to start into growth as easily in the warm days of late fall as they do in the warm days of early spring, many species would come into flower and leaf in those warm autumn spells that we call Indian summer, and the stored food that the plant required for its normal vigorous growth in the following spring would be wasted in a burst of autumn growth, which would be killed by the first heavy freezes, and would be followed by a winter of weakness and probable death. But when two or three months of chilling are necessary before a newly dormant plant will respond to the usual effect of warmth, such plants are protected against the dangers of growth in Indian summer. It is probable that all our native trees and shrubs are thus protected.

Any member of this audience may make, next fall and winter, a simple and instructive experiment with such early spring blooming plants as alder, hazelnut, pussy willow, yellow bush jasmine, forsythia, Japanese quince, peach, and plum. In mid-autumn bring into your living room and set in water freshly cut dormant leafless branches of these plants. They will not bloom. At intervals of a few weeks during late autumn and winter try the same experiment again. You will find that the branches cut at later dates will come into bloom under this treatment. They will not do so, however, until the expiration of the period of chilling appropriate to the various kinds of plants included in the experiment. The required period of chilling varies greatly. In the case of some of the cultivated shrubs about Washington, especially the yellow bush jasmine (*Jasminum nudiflorum*), so brief a period of chilling is required that extraordinarily cold weather in late October or early November may chill them sufficiently to induce them to bloom if a period of warm weather follows in late November. The period of

chilling required for the peach is so short that in Georgia unusually warm weather in December sometimes brings the trees into flower, and their crop of fruit is destroyed by the freezes that follow.

From these facts it appears that our native trees and shrubs are so intimately adjusted to the changes of the climate to which they have been long subjected that they are almost completely protected from injury by freezing, but some of the cultivated species brought from parts of the world having a climate different from ours are only imperfectly adapted to our climatic changes. They grow at times when our native species have learned to hold themselves dormant, and they often suffer severely in consequence.

Chilling, as a protective adaptation, has become a physiological necessity in the life history of cold-winter trees and shrubs. So fixed, indeed, is the habit that it appears to be a critical factor in determining how far such plants may go in the extension of their geographic distribution toward the Tropics. In the Tropics our common northern fruit trees, apples, pears, peaches, cherries, grow well for a time and then become half dormant. In the absence of chilling they never fully recover from their dormancy; they grow with weakened vitality and finally die. If these fruits are to be grown successfully in the tropics they must be given artificially the periodic chilling they require.

When it became evident from the earlier observations and experiments that chilling played so essential a part in the behavior of our trees and shrubs it was clear that additional experiments ought to be conducted in which actively growing plants might be subjected to chilling temperatures without being put in a dark place like the ordinary refrigerator. To meet the requirement of both cold and light a glass-covered, outdoor, brick chamber was constructed in 1912. It was kept above freezing by heating with electric lights, which were turned on and off automatically by a simple thermostat. In summer the chamber was kept cool, though not really cold, by means of ice and electric fans. Although much was learned with this apparatus it was crude and inadequate. To provide for more exact experiments a glass-covered compartment chilled by a refrigerating machine was constructed in one of the Department of Agriculture greenhouses. The refrigerating apparatus is a sulphur-dioxide machine having a refrigerating power equivalent to 1,000 pounds of ice a day. It is run by a 2-horsepower electric motor, and it furnishes ample refrigeration for the lighted compartment, which is a glass-covered frame 25 feet long, 3 feet wide, and 14 to 20 inches in depth. The first of these refrigerated frames was devised and constructed in 1916. In this enterprise I had the valued advice and assistance of Dr. Lyman J. Briggs. The useful-

ness of this refrigerated frame in experimental work with plants was so great that another similar equipment was installed in 1918.

With the aid of this apparatus many of the experiments described in this address have been carried on or verified, as well as other experiments of a related character. For example, at ordinary summer temperatures many kinds of seed will not germinate but remain dormant until death overtakes them. Under the influence of chilling, however, these seeds are stimulated to prompt germination. (See pl. 18.)

The experiments thus far made indicate the importance of a much wider use of the principle of chilling in many lines of experimentation bearing on the improvement of horticultural and agricultural practices. I commend the subject of chilling to experimenters in these lines, and I wish to call especial attention to the desirability of determining proper temperatures for the storage of seeds, bulbs, cuttings, and grafting wood; proper temperatures for the treatment of plants which are to be forced from dormancy to growth at unusual seasons; and proper temperatures for the storage of nursery stock, so that the nurseryman may have plants in proper condition for shipment on any date he desires. (See pls. 19 to 23.)

The whole question of the effect of chilling on herbaceous perennials is an open field.

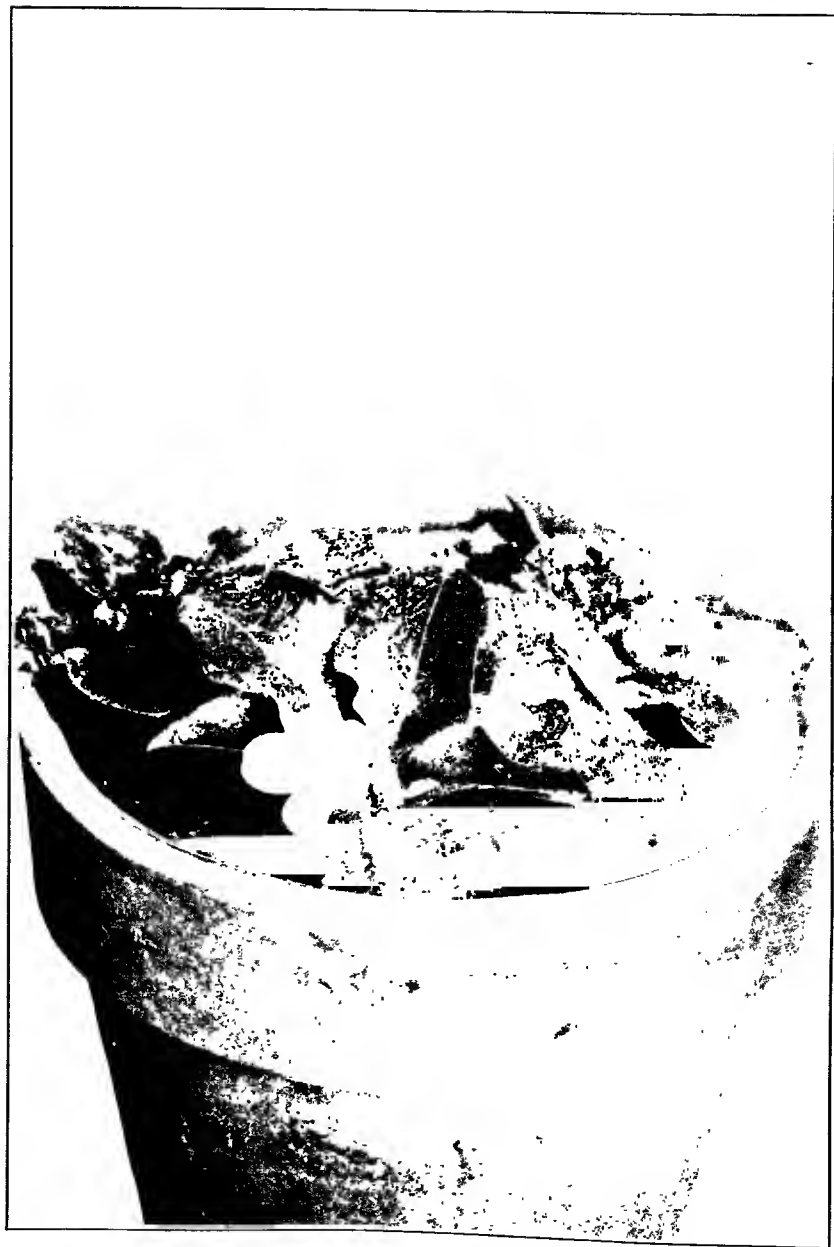
An understanding of the process of chilling explains the reason of some of the practices of gardeners, which they, as well as botanists, have erroneously ascribed to the need of "resting." What a gardener calls "resting" is often in reality a period of chilling, characterized not by physiological rest, but by pronounced internal activity. Rest alone would not, in the case of our cold-climate trees and shrubs, accomplish the purpose the gardener has in mind. It is chilling, not rest merely, that is required. The practice of gardeners and nurserymen known as the "stratification" of seeds is probably to be explained as in reality a process of chilling.

As a single example of the application of the principle of chilling let me cite the case of the blueberry. For several years we have been trying at the Department of Agriculture to domesticate this wild plant. We have raised many thousand hybrids and have set them out in waste sandy lands in the pine barrens of New Jersey. (See pl. 24.) We have grown the bushes to fruiting age and brought them into highly productive bearing. (See pl. 25.) We have made them fruit so lusciously and so abundantly that they have brought returns to the grower at the rate of more than \$1,000 an acre. In a word, we have changed the blueberry from a small wild fruit the size of a pea to a fruit the size of a Concord grape, and we have made its culture a profitable industry. (See pls. 26 and 27.) These things we should not



A PLANT OF BUNCHBERRY, *CORNUS CANADENSIS*, THE SEEDS OF WHICH DO NOT GERMINATE WITHOUT CHILLING.

Bunchberry seeds sowed October 9, 1912, and chilled during the winter germinated promptly the following spring. Another lot of the same seeds sowed on the same date but kept in a greenhouse at a temperature of not less than 52° F. showed no germination in 12 months. These seeds were then chilled for two months at a temperature of 35° to 40° F., and when brought back into the greenhouse they germinated within a month. The very healthy plant shown in the illustration grew from one of these long dormant seeds. The exposure of seeds to winter weather is sometimes practiced by gardeners, but they usually attribute its beneficial effect to freezing, which in all the cases tried in these experiments is unnecessary. (Natural size.)



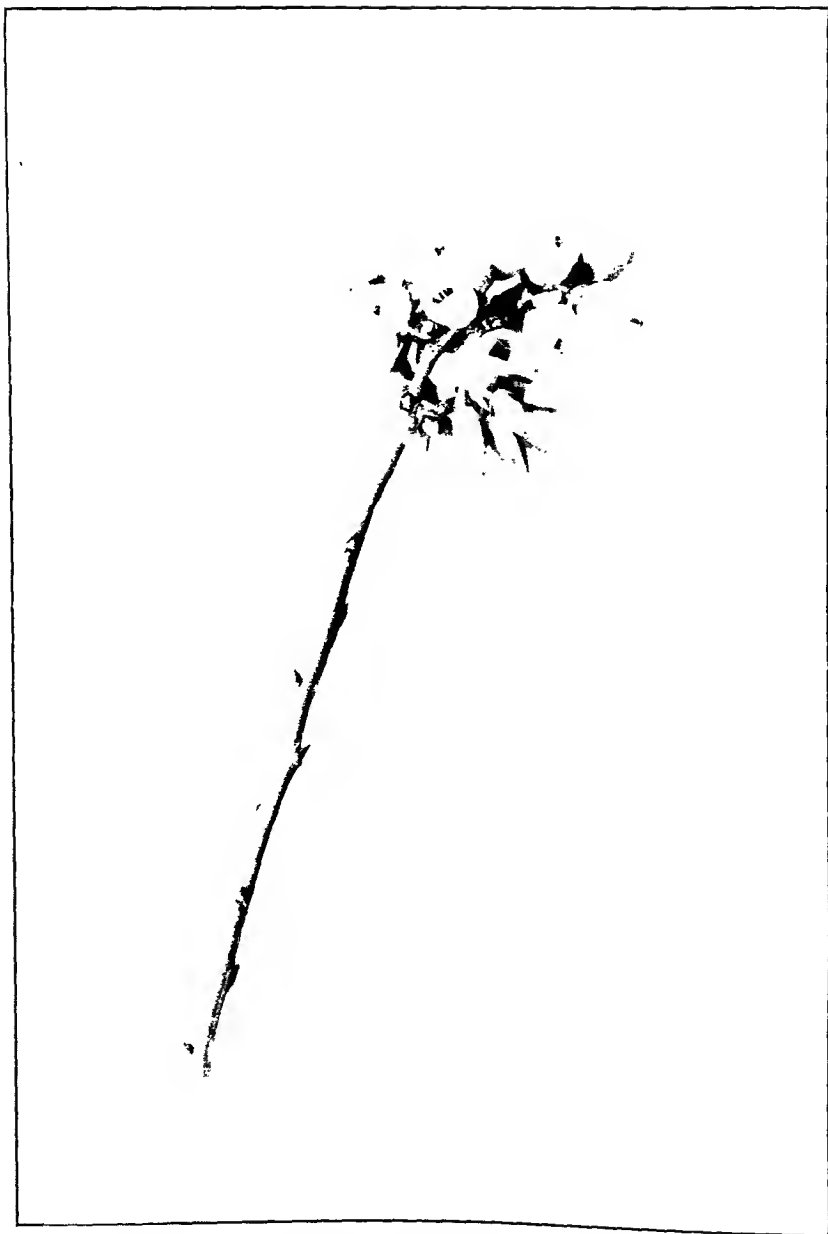
TRAILING ARBUTUS, *EPIGAEA REPENS*, FLOWERING SPARINGLY FROM LACK OF CHILLING.

This plant of trailing arbutus was grown from seed. In the autumn, when about a year old, it laid down clusters of flowering buds. It was kept in a warm greenhouse all winter, but when flowering time came most of its flower buds were dead and brown. Only a single flower opened. (Natural size.)



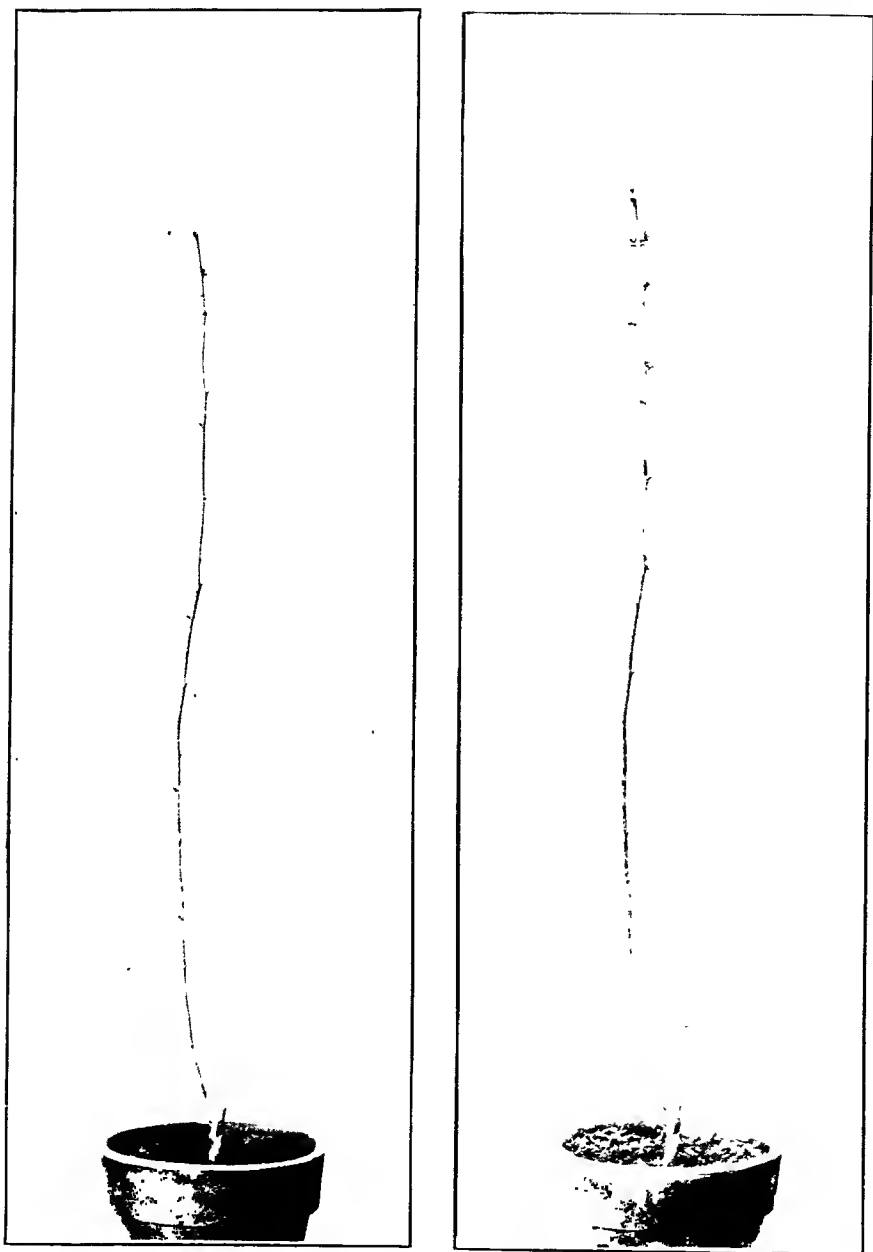
TRAILING ARBUTUS PLANT FLOWERING NORMALLY AFTER CHILLING.

This plant had the same history as the plant described under Plate 19, except that it was kept outdoors during the winter and was brought back into the greenhouse in the spring. At the age of 14 months, when the photograph was taken, March 27, 1911, the plant was in full flower, healthy, and normal. (Natural size.)



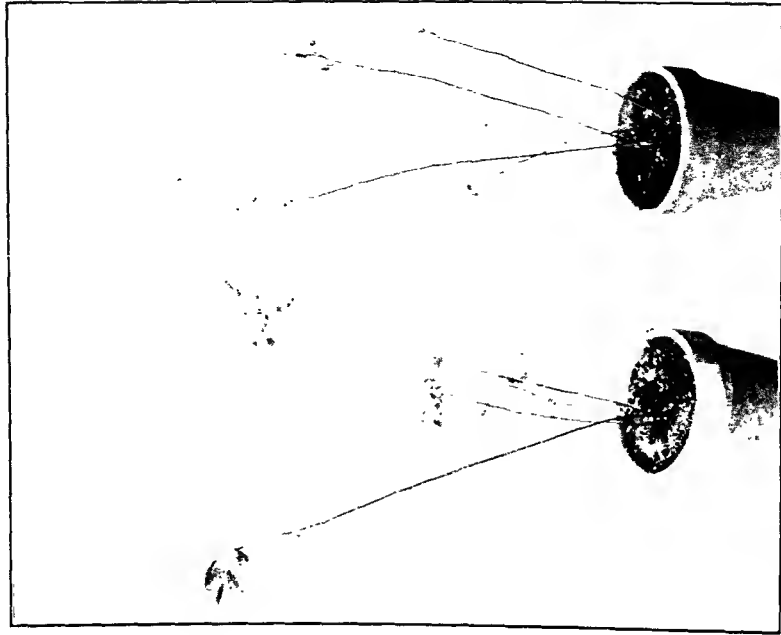
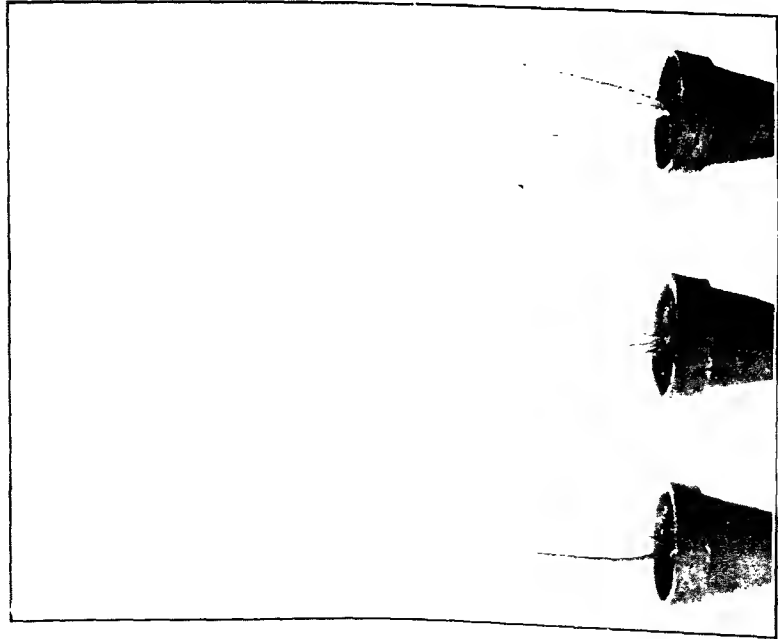
BLUEBERRY PLANT FORCED INTO FLOWER IN SEPTEMBER BY ARTIFICIAL CHILLING.

The plant that bore this cluster of flowers was brought indoors in late winter. It made new growth and during the cool weather of May it laid down flowering buds for the next year, as a blueberry plant ordinarily does in autumn. During the summer, however, the plant was given an artificial winter by chilling it for three months in an artificially refrigerated glass-covered frame exposed to daylight. When brought out of the frame, in September, the plant promptly flowered, as shown in the illustration. (Natural size.)



AWAKENING OF LONG DORMANT PLANTS BY ARTIFICIAL CHILLING.

The illustration consists of two photographs of the same plant. At the left is shown the condition of the plant on December 26, 1916, after more than a year of warmth and dormancy. The figure at the right, from a photograph taken April 27, 1917, shows the appearance of the plant after it had been subjected to artificial chilling for a period of three months and then had been returned to the warm greenhouse. It began to put out new growth from 10 or more of its leafbuds. Even after its extraordinarily long period of dormancy the plant had been brought back to normal activity by a suitable period of chilling. (One-fifth natural size.)



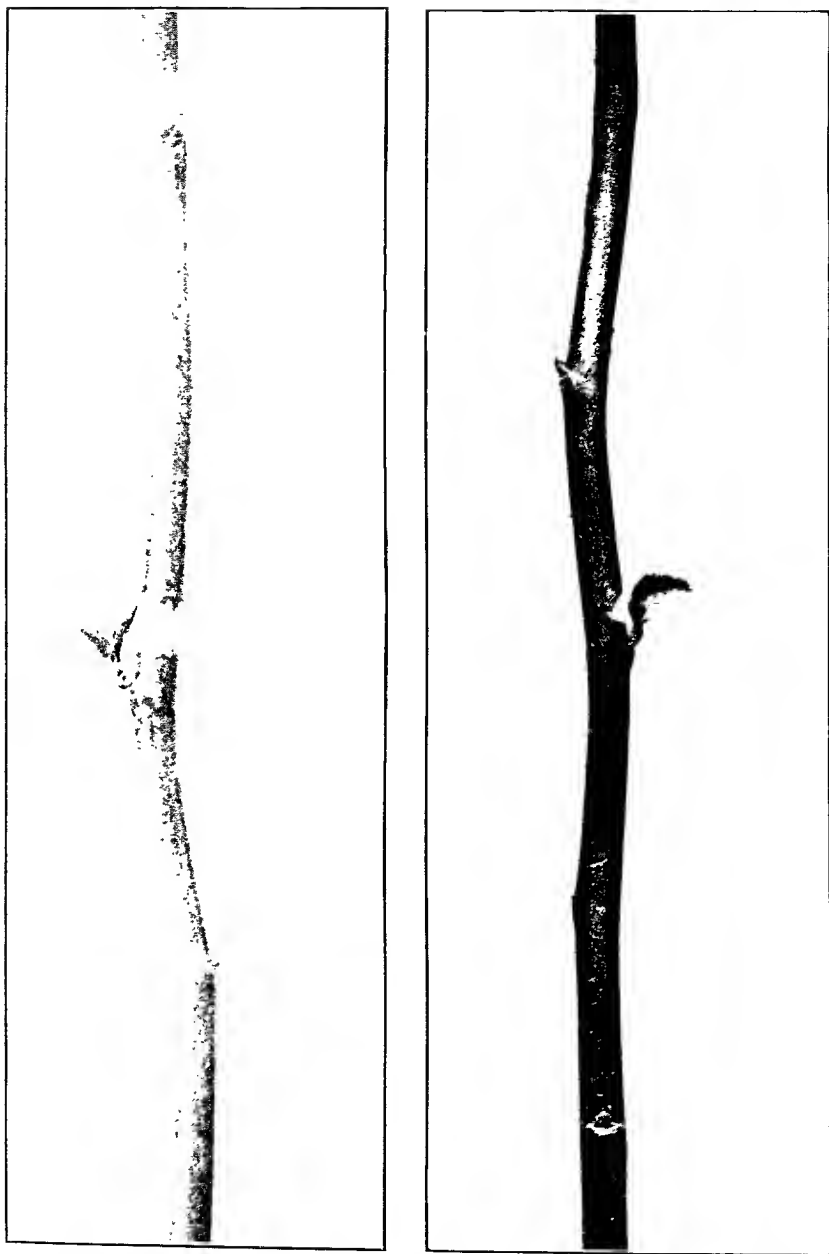
BRINGING A PLANT OUT OF DORMANCY AT A SPECIFIED TIME.

The three blueberry plants at the left, in 2-inch pots, are from a lot that had been kept in a dormant condition by warmth for nearly a year. On October 30, 1917, similar plants were placed under chilling conditions at a temperature of about 35° F. At the end of a month's chilling eight plants were taken out, repotted in 4-inch pots, and brought into a greenhouse maintained at a temperature of 59° to 70° F., and after two months' chilling another eight plants were brought out. Representative plants from each of these two chilled lots are shown at the right of the plate, from a photograph made January 18, 1918. The plant that was kept under refrigeration for a month was only imperfectly chilled and although it started growing the growth was from abnormally few buds. But the plant at the extreme right, under refrigeration for two months was adequately chilled and started into growth from many buds in a normal manner. It is evident that by the proper application of this procedure a plant of this nature can be brought into proper condition for shipment and planting on any date desired.



PLANTATION AT WHITESBOG, N. J., FOR THE TESTING OF BLUEBERRY HYBRIDS.

From very carefully selected wild blueberry plants hybrid seedlings are raised in the greenhouses of the Department of Agriculture at Washington. In order to bring them into fruit under favorable outdoor conditions, so that seedlings of the best hybrids can be made for further propagation, the young seedlings are sent to a plantation at Whitesbog, four miles east of Brown's Mills, in the pine barrens of New Jersey. In the photograph two-year old hybrids are shown at the right, three-year-olds in the row at the left. The rows are 8 feet apart and the plants 5 feet apart in the row.



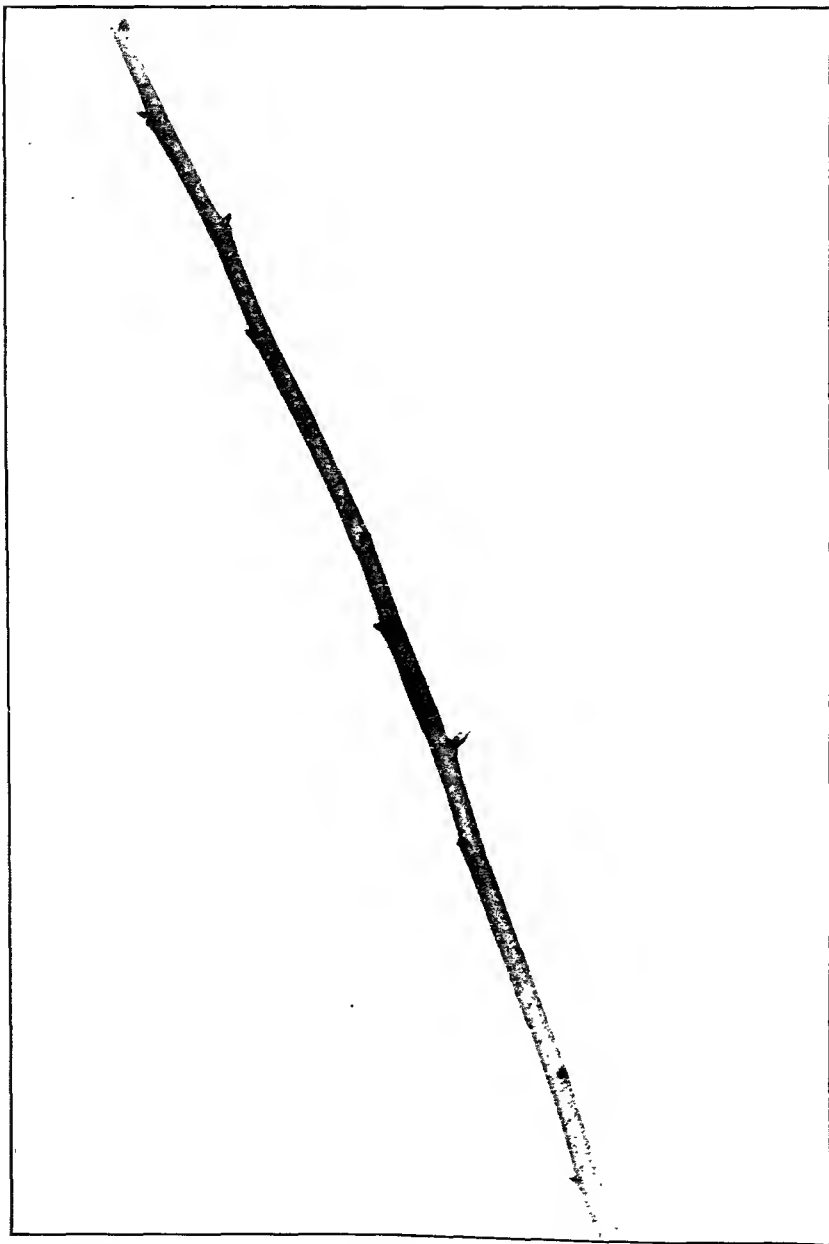
DORMANT WILD CRABS STIMULATED TO GROWTH BY GIRDLING AND BY NOTCHING THE STEM.

These plants had had the same preliminary treatment as the one illustrated in Plate I, that is, they had been kept in the warm greenhouse all winter, without chilling, dormant and leafless. On April 4 a ring of bark was removed from the plant shown in the left-hand figure, and the soft cambium was carefully scraped away down to the hard wood. On April 21, when the photograph was made, the bud next below the girdle had begun to push. In the case of the right-hand plant the stem was notched in early April. The bud next below the notch soon began to grow, and the photograph was taken on May 2. (Natural size.)



DORMANT BLUEBERRY BUDS STIMULATED TO GROWTH BY CHALKING THE STEM.

This plant was brought into the greenhouse February 4, 1913, to be used in breeding experiments. It flowered, but having been insufficiently chilled, only a few of the uppermost leaf buds on each stem grew. In order to keep small ants from crawling up the stems and interfering with the pollination experiments, the stems were chalked near the middle. The dormant buds in and just below the chalked area started growing. The photograph was taken April 5, the stems being rechalked over the same areas that were originally chalked. After numerous repetitions of the experiment it was found that if the chalking was done lightly the buds would not grow, but if the stems were rubbed hard in the process of chalking, as commonly happened in the case of very smooth stems, the buds grew. It was the hard rubbing, not the chalk, that stimulated the growth. (Natural size.)



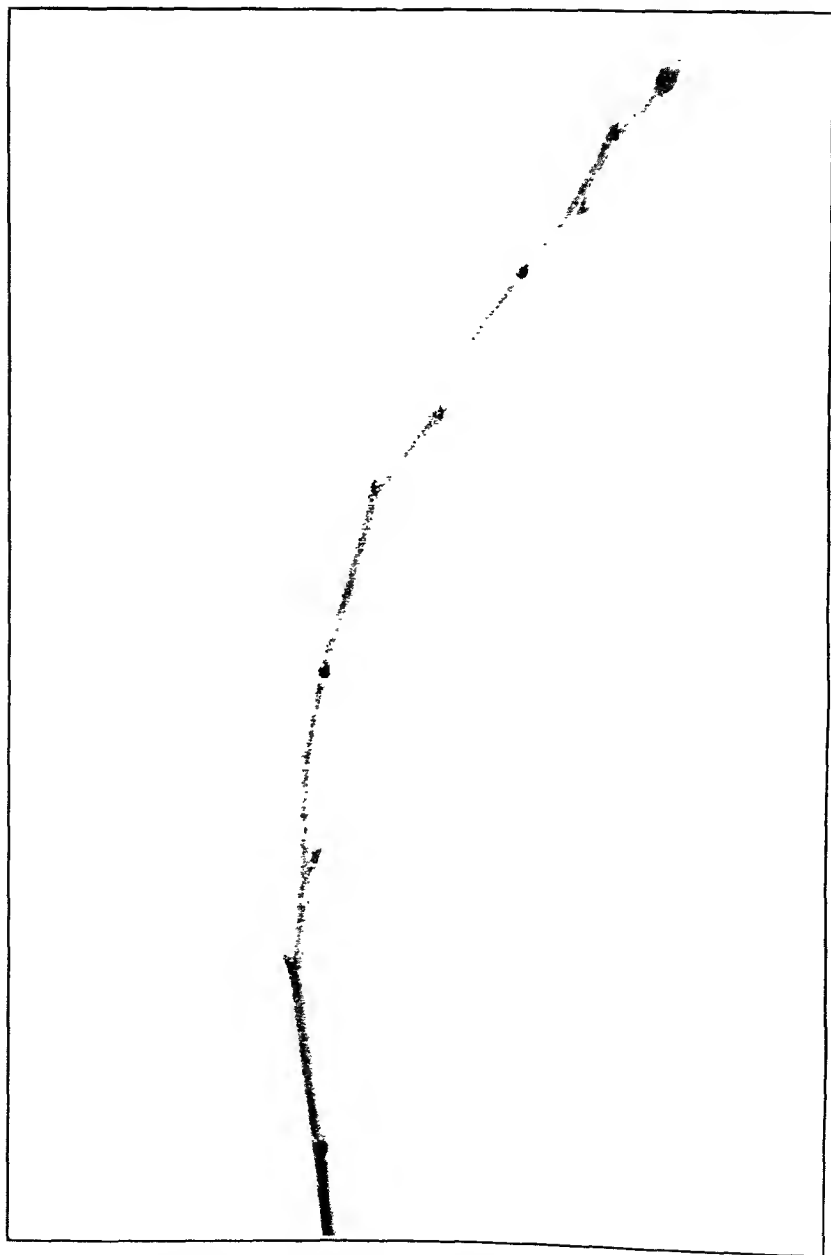
DORMANT BLUEBERRY BUD STIMULATED TO GROWTH BY RUBBING THE STEM.

The photograph, which was taken June 14, 1911, shows a single bud starting into growth on a dormant blueberry plant. The dark area just above the bud is a brown band on an otherwise green stem. It shows the position of a rubbing that was given the stem with a smooth knife handle a few weeks earlier. This bud afterward is grew into a long vigorous branch, while all the other buds remained dormant. (Natural size.)



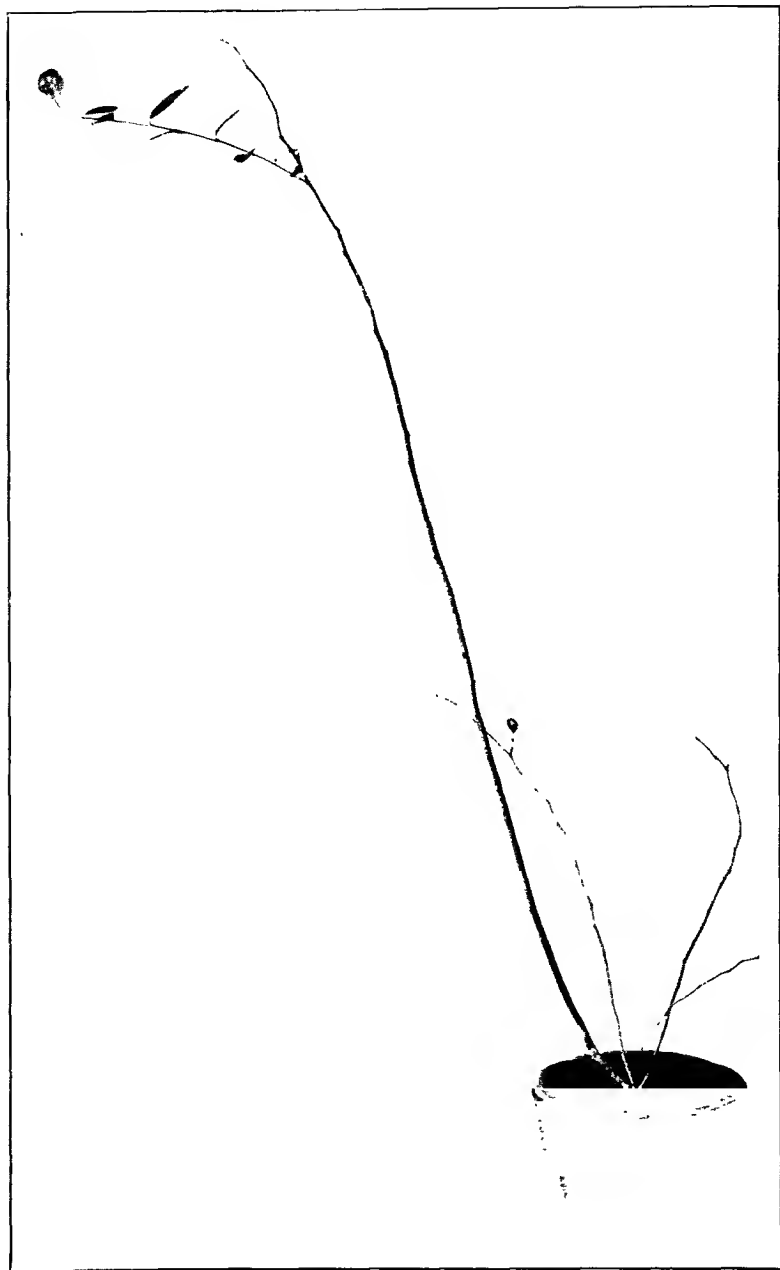
NORMAL SPRING GROWTH ON A BLUEBERRY STEM.

This illustration is from a photograph taken April 24, 1899. In the preceding season the plant had sent up an unbranched shoot. After an outdoor chilling through the winter and early spring it put out flowers and new twigs, as shown in the illustration. The fact to be especially noted is that the new growth on this stem took place from numerous buds. (Natural size.)



ABNORMAL SPRING GROWTH ON A BLUEBERRY STEM, DUE TO LACK OF CHILLING.

This photograph was taken on May 19, 1913. Growth is taking place from only one bud, the third from the tip. The uppermost bud is a flowering bud, the second a leaf bud. Both are dead or dying. This plant has stood in the warm greenhouse all winter and spring. If it had had the usual two or three months of chilling, its starch would have been transformed into sugar and the stem would have flowered and put out new twig growth from numerous buds in the same manner as the stem shown in Plate 14. (Natural size.)

**ABNORMAL GROWTH OF AN UNCHILLED BLUEBERRY PLANT.**

This plant became dormant in the autumn in a warm greenhouse, and not being chilled it continued its dormancy through spring and summer for a period of nine months. Then three of its stems began to die at the tips and, following this, growth began to take place from a single bud next below the dying tip on each stem, as shown in the illustration. For the explanation of this abnormal activity see page 286. The photograph was taken October 12, 1916. (Half natural size.)



BLUEBERRY LEAF EXUDING SUGAR FROM GLANDS INTERPRETED AS OSMOTIC-PRESSURE
SAFETY VALVES.

This is a leaf of the high-bush blueberry, *Vaccinium corymbosum*. The photograph was taken May 19, 1916, and is enlarged four diameters. The sugar-secreting glands, sometimes called extrafloral nectaries, are situated in this plant on the back of the midrib and along the margins of the leaf, toward its base. The drops of sugar solution have been wiped away from the glands on the left-hand margin and from two glands on the midrib at the base of the second and fourth lateral veins above the sugar drop shown near the middle of the picture. This exudation of sugar is interpreted as a means of relief from excessive internal pressure that might burst the cells of the plant or derange its physiological activities.

to expect that some of them will be found to accomplish this act in the same way as our long-dormant greenhouse plants, by the weakening of their cell membranes. This, I have endeavored to show, is in its effect substantially identical with chilling.

6. *The twigs of trees and shrubs after their winter chilling and the transformation of their starch into sugar may be regarded as mechanisms for the development of high osmotic pressures which start the plant into growth.*

Food in the form of starch can not be utilized by a plant directly. The starch must be changed into sugar before it can be used in making new growth. But this transformation does more than make the starch available as food for the growing plant. It serves also to increase the tendency of the cells to swell and enlarge. In the form of starch the material is inert in the creation of osmotic pressures, but when transformed into sugar it becomes exceedingly active. According to the rigid experimental tests of H. N. Morse and his associates, a normal solution of cane sugar at 32° F. has an osmotic power of 25 atmospheres of pressure. It has been demonstrated that there sometimes occur in the cells of plants osmotic pressures as high as 30 atmospheres, or 450 pounds to the square inch, a pressure sufficient to blow the cylinder head off an ordinary steam engine. It can hardly be questioned that these or even much lower osmotic pressures take an important part in forcing open the buds of once dormant plants.

We have evidence that there sometimes arise within the plant osmotic pressures of such intensity as to threaten the rupture of the cells. Consider the case of the exudation of drops of sugar solution from certain specialized glands. When this exudate of sugar occurs in flowers it is known as nectar and it serves a useful purpose to the plant by attracting sugar-loving insects which unconsciously carry pollen from flower to flower and accomplish the beneficial act of cross-pollination. But sugar solution is often exuded outside the flower, in positions, or at times, that preclude any relation to cross-pollination. For example, a blueberry plant during its spring growth, when a leaf has reached nearly full size, is sometimes observed to exude drops of sugar solution from certain glands on the margins of the leaf and on the back of the mid-rib. (See pl. 17.) It is physically impossible that the sugar has left the cells by osmosis. The sugar serves no useful purpose to the plant through the attraction of insects. The exudate certainly can not represent the elimination of a waste product, for sugar is one of the substances most used by plants in forming new tissues. I can conceive of no reason why the plant should exude sugar except to relieve a dangerous physiological condition, namely, the development of excessive osmotic pressures which would burst the cells of the plant or in some other

way derange its physiological activities. I look upon such sugar glands as safety valves for the relief of excessive osmotic pressures that are dangerous to the internal economy of the plant. And not only is this conception applicable to extrafloral nectaries in general, but it may serve also, in the case of floral nectaries, to explain their origin. Having once arisen as osmotic safety valves, the usefulness of the floral nectaries as an aid to cross-pollination would tend strongly to bring about their natural selection and perpetuation.

7. The establishment of a dormant condition before the advent of freezing weather and the continuation of this dormancy through warm periods in late fall and early winter are protective adaptations of vital necessity to the native trees and shrubs.

A little consideration will show how important the principle of chilling is to those species of trees and shrubs which are subjected each year to several months of freezing weather. If they were so constituted as to start into growth as easily in the warm days of late fall as they do in the warm days of early spring, many species would come into flower and leaf in those warm autumn spells that we call Indian summer, and the stored food that the plant required for its normal vigorous growth in the following spring would be wasted in a burst of autumn growth, which would be killed by the first heavy freezes, and would be followed by a winter of weakness and probable death. But when two or three months of chilling are necessary before a newly dormant plant will respond to the usual effect of warmth, such plants are protected against the dangers of growth in Indian summer. It is probable that all our native trees and shrubs are thus protected.

Any member of this audience may make, next fall and winter, a simple and instructive experiment with such early spring blooming plants as alder, hazelnut, pussy willow, yellow bush jasmine, forsythia, Japanese quince, peach, and plum. In mid-autumn bring into your living room and set in water freshly cut dormant leafless branches of these plants. They will not bloom. At intervals of a few weeks during late autumn and winter try the same experiment again. You will find that the branches cut at later dates will come into bloom under this treatment. They will not do so, however, until the expiration of the period of chilling appropriate to the various kinds of plants included in the experiment. The required period of chilling varies greatly. In the case of some of the cultivated shrubs about Washington, especially the yellow bush jasmine (*Jasminum nudiflorum*), so brief a period of chilling is required that extraordinarily cold weather in late October or early November may chill them sufficiently to induce them to bloom if a period of warm weather follows in late November. The period of

chilling required for the peach is so short that in Georgia unusually warm weather in December sometimes brings the trees into flower, and their crop of fruit is destroyed by the freezes that follow.

From these facts it appears that our native trees and shrubs are so intimately adjusted to the changes of the climate to which they have been long subjected that they are almost completely protected from injury by freezing, but some of the cultivated species brought from parts of the world having a climate different from ours are only imperfectly adapted to our climatic changes. They grow at times when our native species have learned to hold themselves dormant, and they often suffer severely in consequence.

Chilling, as a protective adaptation, has become a physiological necessity in the life history of cold-winter trees and shrubs. So fixed, indeed, is the habit that it appears to be a critical factor in determining how far such plants may go in the extension of their geographic distribution toward the Tropics. In the Tropics our common northern fruit trees, apples, pears, peaches, cherries, grow well for a time and then become half dormant. In the absence of chilling they never fully recover from their dormancy; they grow with weakened vitality and finally die. If these fruits are to be grown successfully in the tropics they must be given artificially the periodic chilling they require.

When it became evident from the earlier observations and experiments that chilling played so essential a part in the behavior of our trees and shrubs it was clear that additional experiments ought to be conducted in which actively growing plants might be subjected to chilling temperatures without being put in a dark place like the ordinary refrigerator. To meet the requirement of both cold and light a glass-covered, outdoor, brick chamber was constructed in 1912. It was kept above freezing by heating with electric lights, which were turned on and off automatically by a simple thermostat. In summer the chamber was kept cool, though not really cold, by means of ice and electric fans. Although much was learned with this apparatus it was crude and inadequate. To provide for more exact experiments a glass-covered compartment chilled by a refrigerating machine was constructed in one of the Department of Agriculture greenhouses. The refrigerating apparatus is a sulphur-dioxide machine having a refrigerating power equivalent to 1,000 pounds of ice a day. It is run by a 2-horsepower electric motor, and it furnishes ample refrigeration for the lighted compartment, which is a glass-covered frame 25 feet long, 3 feet wide, and 14 to 20 inches in depth. The first of these refrigerated frames was devised and constructed in 1916. In this enterprise I had the valued advice and assistance of Dr. Lyman J. Briggs. The useful-

ness of this refrigerated frame in experimental work with plants was so great that another similar equipment was installed in 1918.

With the aid of this apparatus many of the experiments described in this address have been carried on or verified, as well as other experiments of a related character. For example, at ordinary summer temperatures many kinds of seed will not germinate but remain dormant until death overtakes them. Under the influence of chilling, however, these seeds are stimulated to prompt germination. (See pl. 18.)

The experiments thus far made indicate the importance of a much wider use of the principle of chilling in many lines of experimentation bearing on the improvement of horticultural and agricultural practices. I commend the subject of chilling to experimenters in these lines, and I wish to call especial attention to the desirability of determining proper temperatures for the storage of seeds, bulbs, cuttings, and grafting wood; proper temperatures for the treatment of plants which are to be forced from dormancy to growth at unusual seasons; and proper temperatures for the storage of nursery stock, so that the nurseryman may have plants in proper condition for shipment on any date he desires. (See pls. 19 to 23.)

The whole question of the effect of chilling on herbaceous perennials is an open field.

An understanding of the process of chilling explains the reason of some of the practices of gardeners, which they, as well as botanists, have erroneously ascribed to the need of "resting." What a gardener calls "resting" is often in reality a period of chilling, characterized not by physiological rest, but by pronounced internal activity. Rest alone would not, in the case of our cold-climate trees and shrubs, accomplish the purpose the gardener has in mind. It is chilling, not rest merely, that is required. The practice of gardeners and nurserymen known as the "stratification" of seeds is probably to be explained as in reality a process of chilling.

As a single example of the application of the principle of chilling let me cite the case of the blueberry. For several years we have been trying at the Department of Agriculture to domesticate this wild plant. We have raised many thousand hybrids and have set them out in waste sandy lands in the pine barrens of New Jersey. (See pl. 24.) We have grown the bushes to fruiting age and brought them into highly productive bearing. (See pl. 25.) We have made them fruit so lusciously and so abundantly that they have brought returns to the grower at the rate of more than \$1,000 an acre. In a word, we have changed the blueberry from a small wild fruit the size of a pea to a fruit the size of a Concord grape, and we have made its culture a profitable industry. (See pls. 26 and 27.) These things we should not



A PLANT OF BUNCHBERRY, *CORNUS CANADENSIS*, THE SEEDS OF WHICH DO NOT GERMINATE WITHOUT CHILLING.

Bunchberry seeds sowed October 9, 1912, and chilled during the winter germinated promptly the following spring. Another lot of the same seeds sowed on the same date but kept in a greenhouse at a temperature of not less than 55° F., showed no germination in 12 months. These seeds were then chilled for two months at a temperature of 45° to 46° F., and when brought back into the greenhouse they germinated within a month. The very healthy plant shown in the illustration grew from one of these long dormant seeds. The exposure of seeds to winter weather is sometimes practiced by gardeners, but they usually attribute its beneficial effect to freezing, when in all the cases tried in these experiments it is necessary to chill.

(PLATE 18.)



TRAILING ARBUTUS, *FRAGARIA ALPENSIS*, FLOWERING SPARINGLY FROM LACK OF CHILLING.

This plant of trailing arbutus was grown from seed. In the autumn, when about a year old, it laid down clusters of flowering buds. It was kept in a warm greenhouse all winter, but when flowering time came most of its flower buds were dead and brown. Only a single flower opened. (Natural size.)



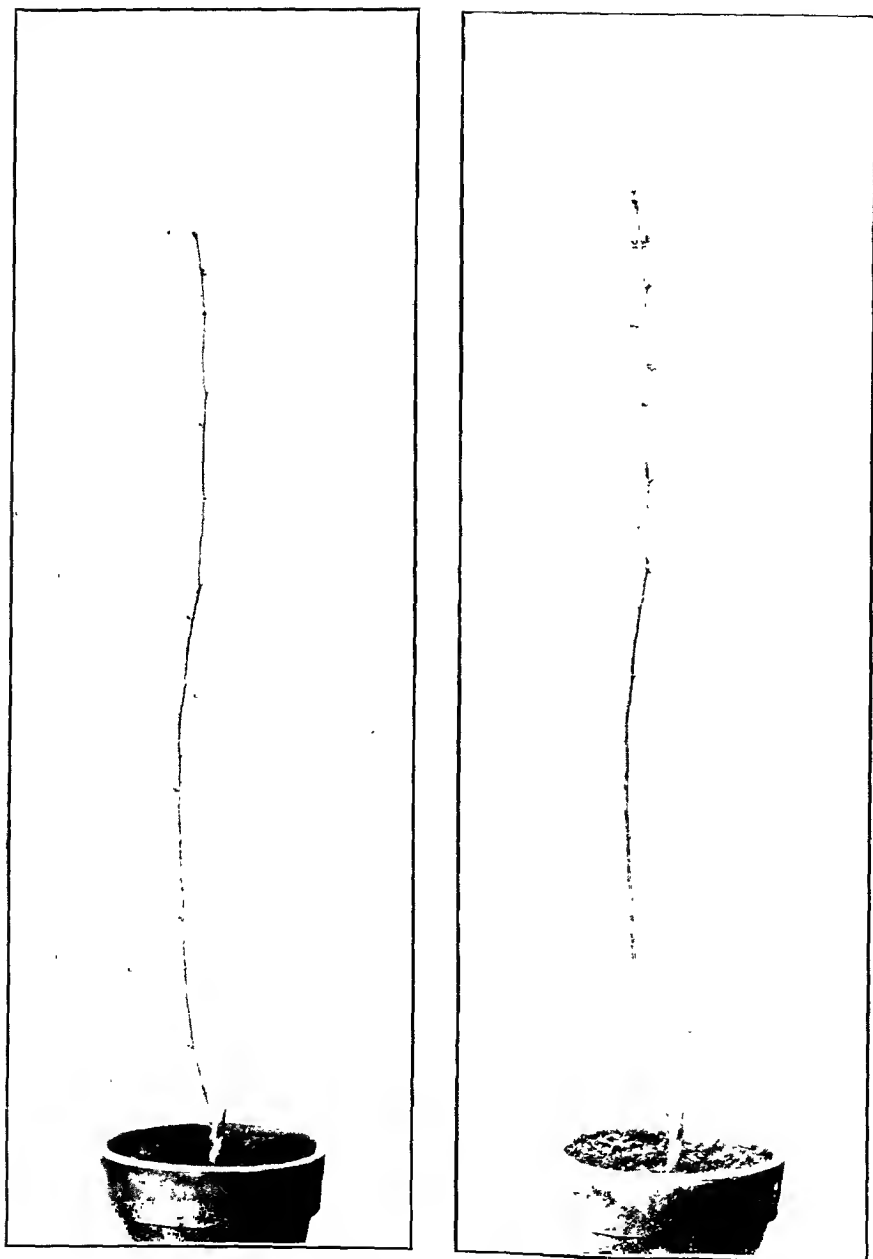
TRAILING ARBUTUS PLANT FLOWERING NORMALLY AFTER CHILLING.

This plant had the same history as the plant described under Plate 19, except that it was kept outdoors during the winter and was brought back into the greenhouse in the spring. At the age of 11 months, when the photograph was taken, March 27, 1911, the plant was in full flower, healthy, and normal. (Natural size.)



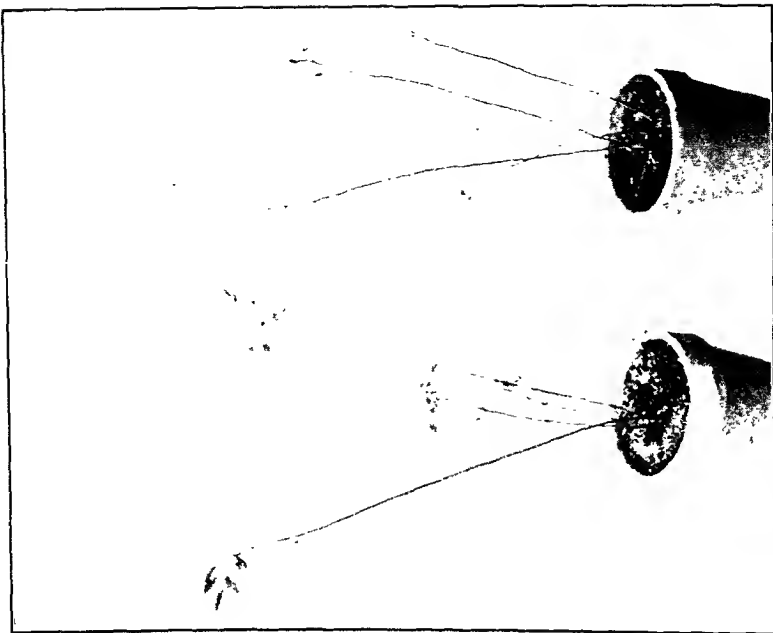
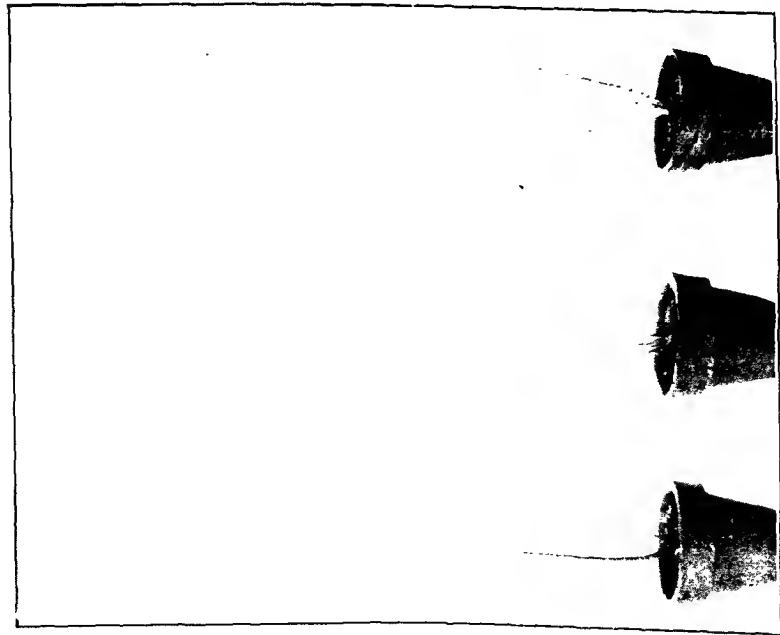
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The plant that bore this cluster of flowers was brought indoors in late winter. It made new growth and during the cool weather of May it laid down flowering buds for the next year, as a blueberry plant ordinarily does in autumn. During the summer, however, the plant was given an artificial winter by chilling it for three months in an artificially refrigerated glass-covered frame exposed to daylight. When brought out of the frame, in September, the plant promptly flowered, as shown in the illustration. (Natural-size.)



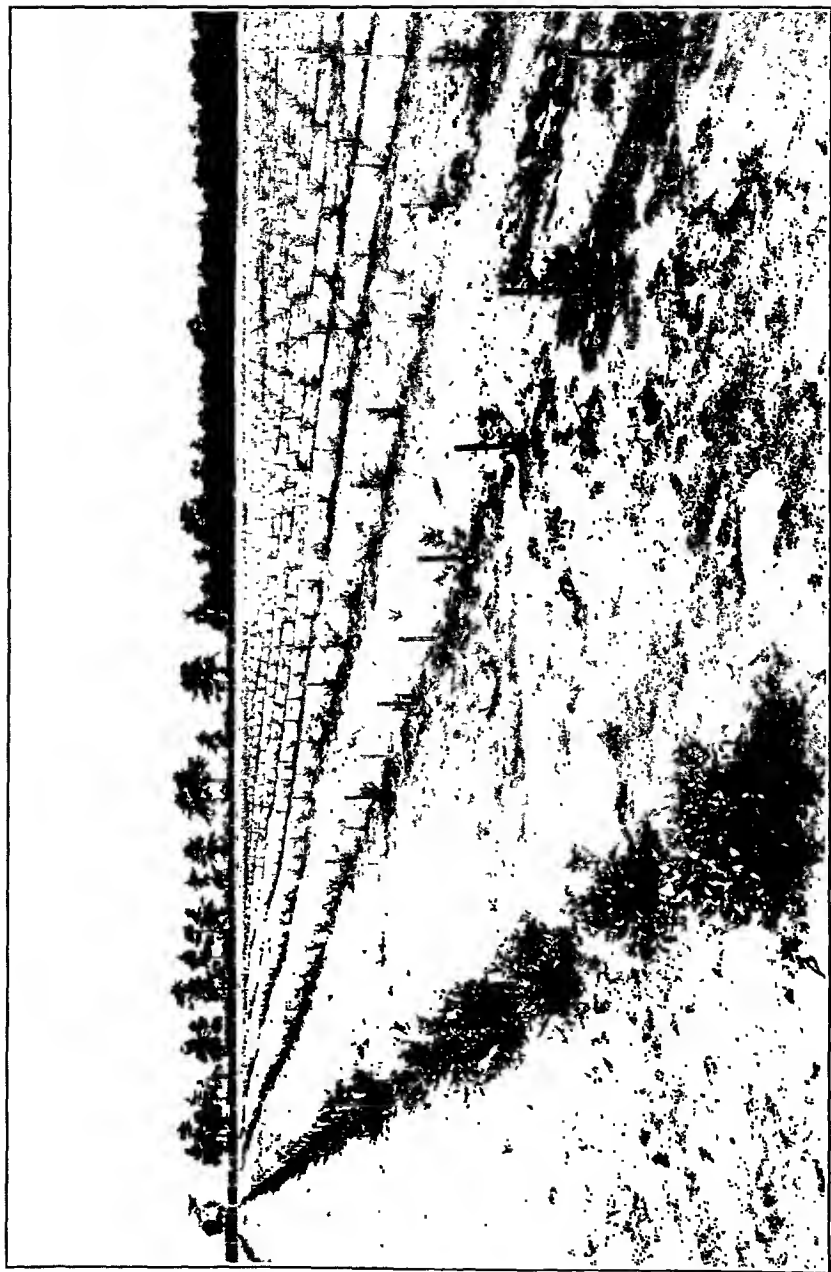
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BRINGING A PLANT OUT OF DORMANCY AT A SPECIFIED TIME.

The three blueberry plants at the left, in 1-inch pots, are from a lot that had been kept in a dormant condition by warmth for nearly a year. On October 30, 1917, similar plants were placed under chilling conditions at a temperature of about 32° F. At the end of a month's chilling eight plants were taken out, repotted in 1-inch pots, and brought into a greenhouse maintained at a temperature of 60° to 70° F. and after two months' chilling another eight plants were brought out. Representative plants from each of these two chilled lots are shown at the right of the plate, from a photograph made January 18, 1918. The plant that was kept under refrigeration for a month was only imperfectly chilled and although it started growing, the growth was from abnormally low buds. But the plant at the extreme right, under refrigeration for two months, was adequately chilled and started into growth from many buds in a normal manner. It is evident that by the proper application of this procedure a plant of this nature can be brought into proper condition for shipment and planting on any date desired.



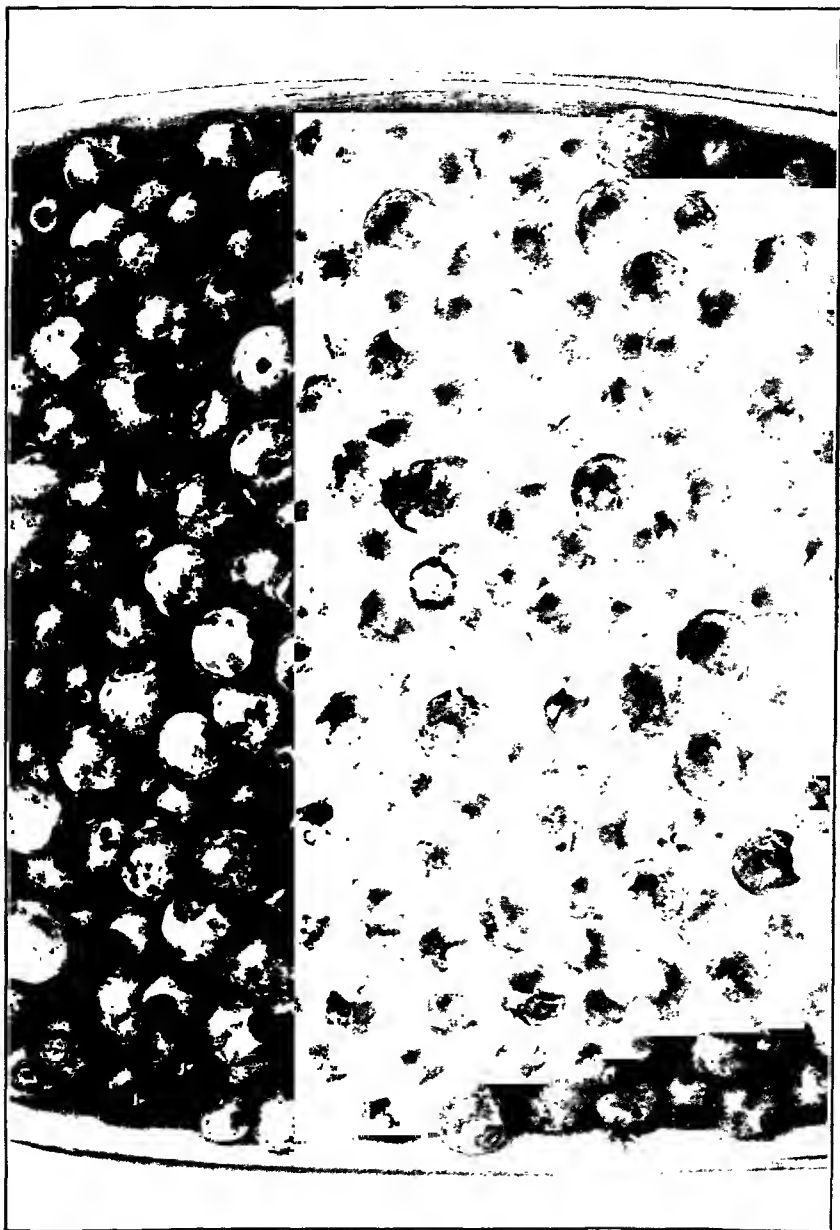
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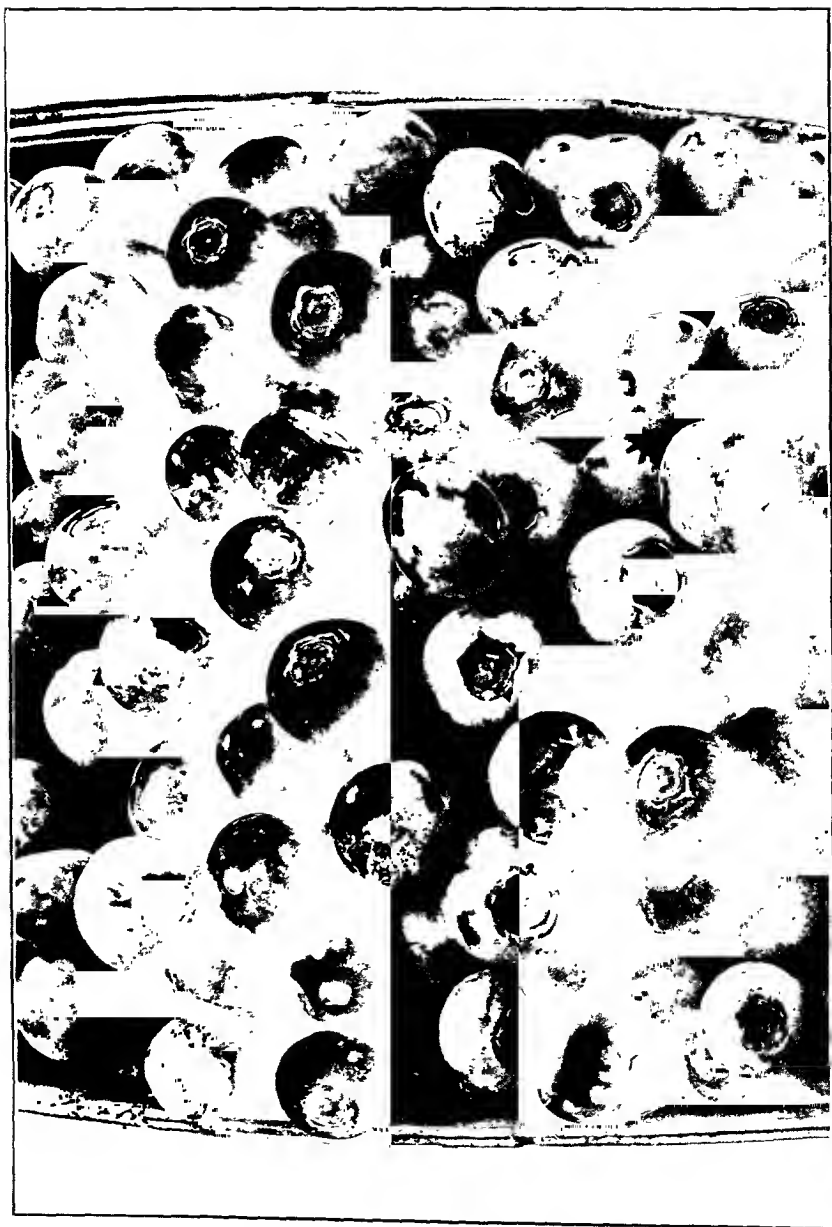
FOUR-YEAR-OLD BLUEBERRY HYBRID IN FULL FRUIT.

This illustration shows the vigor, beauty, and productiveness of a hybrid blueberry bush when it is given the proper and peculiar conditions which by its nature it requires for successful growth. From a one-third-acre patch of hybrid bushes was secured in 1919 a yield of berries at the rate of 36 bushels per acre. They sold at a little over \$10 a bushel, bringing gross receipts at the rate of \$366 per acre. In 1920 this planting yielded at the rate of 117 bushels per acre, which sold at a little less than \$11 a bushel, yielding gross receipts at the rate of \$1,287 per acre.



THE ORDINARY WILD BLUEBERRY OF NEW JERSEY.

THE purpose of this photograph is to show the berries of a quart box of wild New Jersey blueberries rather better than the purpose of comparison with the selected hybrid blueberries.



FRUIT OF A SELECTED HYBRID BLUEBERRY.

This illustration shows, in natural size, a quart box of blueberries from a hybrid produced at Washington and fruited at Whitesbog. The photograph represents the average product of the bush, for it was taken from a lean picking, including the small berries as well as the large ones. Hybrid berries of still larger size have been fruited at Whitesbog.

have been able to do unless we had first worked out the principle of chilling, an understanding of which was essential to our work of breeding and propagation.

In conclusion I wish to express the opinion that the chilling of dormant trees and shrubs of temperate climates as a prerequisite to their resumption of normal growth in spring ought to be recognized in books on plant physiology as one of the normal processes in plant life. These works should contain chapters on chilling, just as they now contain chapters on other fundamental factors and principles relating to the life history of plants. And especially in books on plant physiology in relation to agriculture should the subject of chilling be dealt with in detail, for when in the pursuit of agriculture we take plants from one part of the world to another, or undertake to grow them out of season, or attempt to propagate them in quantity by grafting or by other processes unknown in nature, we are greatly handicapped and limited in our operations if we do not understand the principles of a process so widely existent in nature and so indispensable to a large proportion of the plants of temperate agriculture as the process of chilling.

FLORAL ASPECTS OF BRITISH GUIANA

By A. S. HITCHCOCK.

[With 12 plates.]

Through the cooperation of the United States Department of Agriculture, the Gray Herbarium of Harvard University, and the New York Botanical Garden a visit was made to British Guiana for the purpose of studying its flora and collecting specimens of the flowering plants and ferns. The observations were made between October 22, 1919, and February 2, 1920.¹

British Guiana, a British colony in northern South America, lying between Venezuela and Dutch Guiana, and between the Atlantic Ocean and Brazil, has an area of 90,277 square miles.² It extends along the Atlantic coast about 270 miles and southward 540 miles on the western and 300 miles on the eastern side (lat. 1° to 8° N., long. 57° to 61° W., approximately).

There are three important rivers approximately parallel flowing northward into the ocean besides the Courantyne which forms the eastern boundary. These are, from west to east, the Essequibo, the Demerara, and the Berbice. The Essequibo is one of the large rivers of the world, receiving two important tributaries from the west, the Mazaruni and the Cuyuni.

The coastal region is a low swampy alluvial belt almost 10 miles deep on the western border and about 40 miles deep along the Courantyne. Much of this is below the level of high tide and the water is excluded by dikes and sea walls. In places the land may be as much as 10 feet above high water but the general impression to the eye is a perfectly level plain. Approaching the coast from the sea one notes first the tall chimneys of sugar factories and occasional tall trees before any other sign of land is visible.

Next to this coastal region there is a broad belt of higher somewhat undulating land interspersed with sand dunes and clay hills, but of scarcely more than 200 feet elevation anywhere. Still farther south and west there is a series of plateaus 1,200 to 2,000 feet in altitude. When streams descend from one plateau to another there are

¹ An account of the itinerary will be found in the *Journal of the New York Botanical Garden*, July, 1920.

² Much of the statistical matter is taken from the *British Guiana Handbook* for 1913, the second and last edition.

gorges and waterfalls. One of the most beautiful of the falls is Kaieteur Falls, 741 feet high and 400 feet wide. The only mountains as distinguished from hills lie on the border in the region where



FIG. 1.—South America, showing position of British Guiana.

British Guiana, Venezuela, and Brazil join. The culminating peaks are Roraima and Kukenaam, table mountains with precipitous sides rising 5,000 feet above the plateau and reaching an altitude of about

8,600 feet. The general level of the savanna region in the southern part of the Colony is only about 300 to 400 feet.

The region was first settled by the Dutch at Kyk-over-al about 1615. This place is a little island a few miles above Bartica in the Mazaruni River near Kartabo. Settlements were later made on the Essequibo, Demerara, and Berbice Rivers, which grew into colonies. These passed to Great Britain about 1815 and were united into the colony of British Guiana in 1831. The names of the original colonies are preserved in the names of the counties into which the Colony is divided. The county of Essequibo includes the drainage system of the Essequibo River and the coastal region west to Venezuela; the much smaller county of Demerara includes the drainage system of the Demerara River and, along the coast, to the Abary River. The county of Berbice includes the drainage system of the Berbice River and east to the boundary, which is the Courantyne River.

The means of communication are mainly by boat. The rivers are navigable for some distance (50 to 60 miles) but are finally much interrupted by rapids. Beyond steamer or launch navigation progress is slow, by canoes and small boats, with frequent portages. There is practically no communication in the interior by roads. There are paths here and there to connect one river with another, but supplies must be carried by porters. The longest trip that one can make inland without a special outfit is from Georgetown to Tumatumari on the Potaro River. This is accomplished as follows: By steamer (three times a week) to Wismar on the Demerara River; by rail to Rockstone on the Essequibo (rapids prevent the ascent of the Essequibo); the following morning by launch to Tumatumari, arriving from 6 to 10 p. m., according to conditions. There are good rest houses at Rockstone and Tumatumari. The rapids at the latter point prevent a further ascent of the Potaro, but a small launch runs above the rapids a few miles to Potaro Landing to supply a gold-mining company. A trip up the Essequibo to the Rupununi cattle region of the southern part of the colony is said to take a minimum of three weeks from Georgetown. A railroad runs along the coast from Georgetown to Rosignol opposite New Amsterdam, and another from Vreed-en-Hoop, opposite Georgetown, to Parika on the Essequibo. In the immediate vicinity of the coast there are good automobile roads.

The climate is strictly tropical, but is tempered by the trade wind. The mean monthly rainfall at Georgetown is as follows (1880-1912):

January	8.36	August	6.31
February	6.78	September	3.01
March	7.49	October	2.35
April	7.25	November	5.26
May	11.50	December	11.46
June	12.06		
July	10.61	Total	91.23

It will be seen from this that there are two wet and two dry seasons, though these are not very sharply defined. The long dry

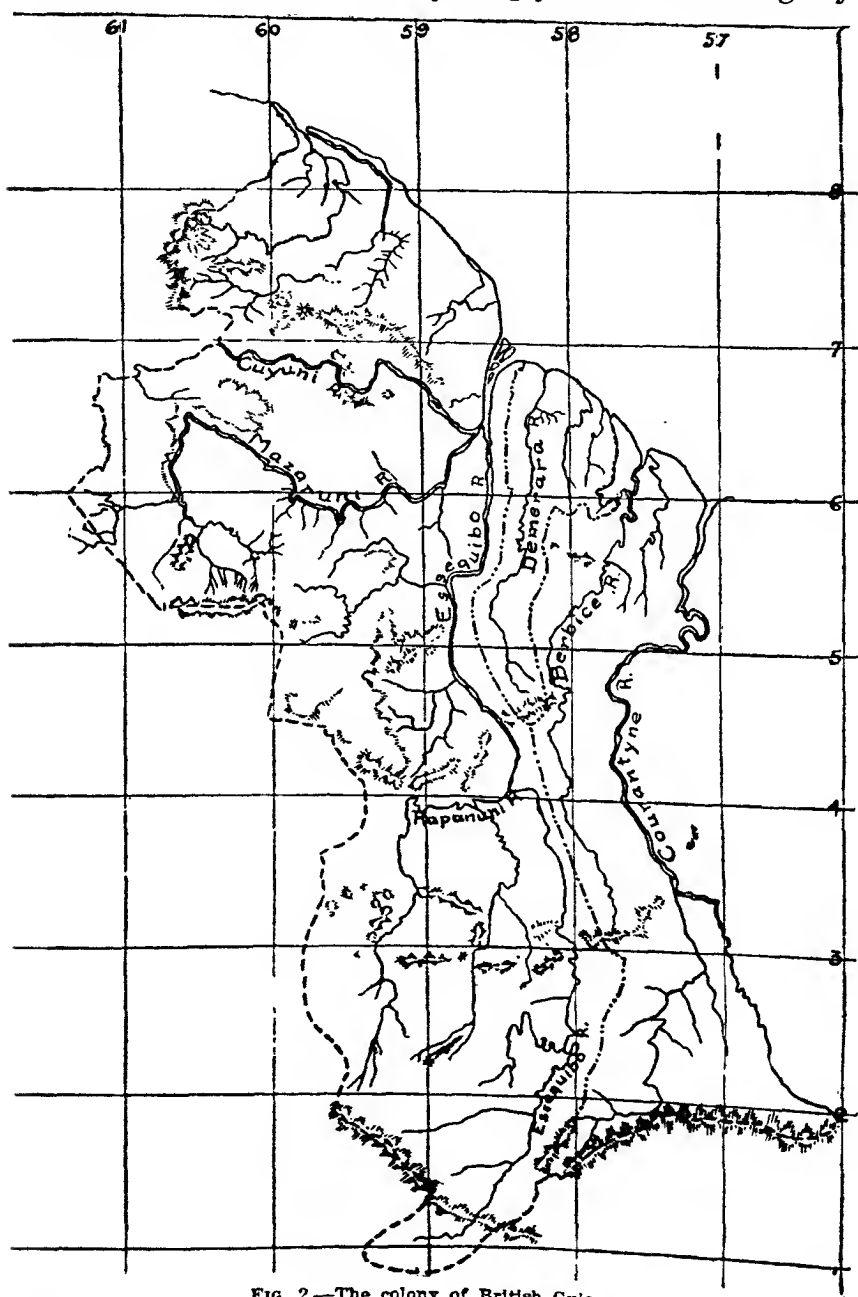


FIG. 2.—The colony of British Guiana.

season from August to November is usually to be depended upon, but the other seasons vary. On the lower Essequibo the rainfall may

rise to over 150 inches, while in the savanna region of the south it may fall to 50 inches.

The temperature near the coast is very uniform. The mean maximum (Fahrenheit) is 83° in the winter and 87° in the summer, while the mean minimum ranges between 74.5° and 76.5°. In the hottest part of the year, the long dry season, August to November, the temperature (shade) rarely goes higher than 88° and at night falls to about 80°. In the winter it rarely falls below 74° and usually rises only to 82° to 84°. The temperature in the sun is strikingly high in contrast (140° to 145°). The humidity is always high. Because of this it is uncomfortable to be out of the air currents. The houses are raised on pillars and the structure is open to allow a free circulation. Clothing and leather mold quickly.

The population of the entire colony is about 300,000. The percentage of the different races is given in the Handbook (1913) as follows: Europeans, 1.3; Portuguese, 3.4; East Indians, 42.7; Chinese, 0.9; Negroes, 39; mixed races, 10.2; aborigines, 2.3. The population of Georgetown is about 60,000, of which 4.5 per cent are whites, and of New Amsterdam, about 9,000. The great majority of the people are to be found near the coast.

The drinking water of the coast region is obtained from rain water caught in tanks. The general water supply of Georgetown and the neighboring plantations is obtained from the East Coast Water Conservancy. This is a swampy area lying southeast of the city. Dikes have been built to impound the water in several square miles behind the river and coast plantations and extending east to a dike near the Mahaica River. The south limit is the slightly higher land back of the swampy area. The water is led to its destination by a series of canals.

The drainage of Georgetown is intertidal. There is an outflow during low tide and tide gates shut out the sea water during high tide.

The health of the colony is fairly satisfactory. There is no yellow fever, but malaria and dysentery are rather common. The death rate is about 35 per thousand among the population as a whole, but only 14.8 among the whites. On account of the drainage system and the open canals it is difficult to protect the lower class of the population largely made up of East Indians and Negroes.

The industries are mainly agricultural, though the production of gold and diamonds is of some importance. There are large deposits of bauxite (an oxide of aluminum) which are just commencing to be exploited. Timber is also an important minor industry. There are many kinds of woods exported, the best known probably being the greenheart (*Nectandra rodioei*), a wood much used for piles, lock gates, and other structures in contact with salt water, be-

a greater importance because of the conditions favorable to increased profit. Sugar and its by-products constitute about three-fourths the value of all exports. The sugar plantations are found along the coast in the alluvial plain from the Pomeroon district to the Courantyne River and along the rivers for a few miles above where they empty into the sea. Especially are the sugar plantations found along the "East Coast," the coast east of Georgetown, and the "West Coast," the coast between the Demerara and Essequibo rivers, and the "East Bank" of the Demerara, for a few miles south of Georgetown.

In recent years rice has assumed some importance as an export crop. Other agricultural products are coconuts, cacao, coffee, rubber (*Hevea brasiliensis*), and limes, all of minor importance. Fruits are grown locally but, aside from limes, are scarcely of commercial importance.

Cattle raising is carried on in connection with the sugar plantations, but more extensively in the Rupununi district, an upland savanna region of the southern part of the colony. This is an eastward extension of the great savannas of Venezuela. The cattle are exported to Brazil as the communication with that country by way of the Rio Branco and thus to Manaus is easier than through the forest region to the coast of British Guiana. Recently a cattle trail has been cut through and one or two herds of cattle have been brought north successfully.

The chief native food plants of the colony are the yam (*Dioscorea* sp.), cassava (*Manihot utilisima*), eddo and tannia (*Colocasia esculenta* or allied species), the sweet potato (*Ipomaea batatas*), rice (*Oryza sativa*), plantain (*Musa paradisiaca*), and several legumes such as the pigeon pea (*Cajanus indicus*) and the bonavist or bonnyvis (*Dolichos lablab*). The bread fruit (*Artocarpus incisa*) is grown to a limited extent.

The common vegetables are the tomato, egg plant or boulanger, the okra or gumbo (*Hibiscus esculentus*) and several kinds of pumpkins and squashes.

Peppers in great variety are much grown for flavoring and the sorrel or roselle (*Hibiscus sabdariffa*) for making acid drinks.

The flora of British Guiana has been made known chiefly through the collections of Jenman, who was superintendent of the Castleton Gardens in Jamaica from 1873 to 1879 when he came to Georgetown as government botanist and superintendent of the botanical garden. The first collections of importance were made by Schomburgk who made two journeys into the interior (1835-1839 and 1840-1844) the second for the purpose of fixing the boundaries of the colony. The Jenman collection forms the basis of the herbarium at the botanical garden of Georgetown and is known officially as the Jenman Her-

barium. This collection is well arranged and is in good cases accessible for study in the director's office at the garden. The collection contains also specimens collected by Im Thurn on Roraima; by McConnell and Quelch at the same place; and by Bartlett, Stockdale, Abraham, and other recent botanists connected with the botanical garden.

The official botanical work of the colony is now under the general direction of Prof. J. B. Harrison, Director of Science and Agriculture.

Originally nearly all of British Guiana was covered with forest, the exceptions being the upland savanna region of the Rupununi District in the southern part of the colony mostly between 3° and 5° latitude, and the coastal savannas which are marshy areas. The forest has been removed in part from the areas under cultivation which, however, are a small proportion of the whole.

To the visitor the plants that first attract attention are those cultivated for ornament. Some of these are natives of some part of the colony, but many are exotics. A striking feature of the Tropics is the palms, of which many species are to be found in Georgetown. There is a fine collection in the botanical garden. The coconut (*Cocos nucifera*), a conspicuous feature of the landscape, is common here as on all tropical shores. The cabbage palm (*Oreodoxa oleracea*) is commonly planted along streets and gives an especially fine effect when adult trees form long rows on either side of avenues. The cabbage palm resembles the coconut, both having pinnate leaves, but in the former the inflorescence is borne some distance below the crown of leaves, while in the latter it is borne in the axils of the leaves of the crown. The royal palm (*Oreodoxa regia*) is less common than the cabbage palm and can be distinguished by the very smooth even trunk which bulges in the middle.

Among the native palms may be mentioned the eta palm (*Mauritia flexuosa*) with palmate leaves and large clusters of small fruits about an inch in diameter; the manicole (*Euterpe edulis*) with very slender erect stem, and the troolie (*Manicaria saccifera*) much used for thatching. One of the climbing forms (*Desmoncus* sp.) is a great nuisance to the collector because of the prolonged midribs, covered with reflexed thorns, the ends dangling in the air to catch the unwary traveler.

There is a great variety of trees planted along the streets and in the parks of Georgetown, all of much interest to the botanist. Only a few of these can be mentioned here. Probably the commonest of the conspicuous trees is the saman or raintree (*Pithecolobium saman*, *Samanea saman*), with a graceful rounded widely spreading top. The flame tree or flamboyant (*Delonix regia*, *Poinciana regia*), bears large clusters of showy scarlet flowers that cover the tree when the

leaves have dropped. The frangipani (*Plumiera alba*) has white flowers and large stubby twigs that give the tree a coarse ugly appearance when the leaves have fallen. The cannonball tree (*Couroupita guianensis*) is curious in that it bears the flowers and fruits in a tangle of short branches along the trunk between the foliage branches and the ground. The fruits are globose, russet-brown, about 6 inches in diameter, and evil-smelling, though the flowers are sweet scented. The queen of flowers (*Lagerstroemia speciosa*), a tall tree, and the crape myrtle (*Lagerstroemia indica*), a large shrub, are frequent in parks and gardens. In Georgetown the first of these is frequently called king of flowers and the second queen of flowers.

Among the shrubs one sees the hibiscus (*Hibiscus rosa-sinensis*) with many varieties, the rose of Sharon (*H. syriacus*), and the coral hibiscus (*H. schizopetalus*). The crotons (*Codiaeum variegatum*) are present in endless varieties, cultivated because of the beautifully mottled, often spirally twisted, leaves. The copper leaf (*Acalypha wilkesiana*) is also cultivated for its bronze green or mottled foliage, the leaves being heart shaped. A rather common hedge plant is *Nothopanax guilfoylei*, with white-margined leaflets.

There are several ornamental vines. The most conspicuous is the bougainvillea, a truly gorgeous plant when in full flower. There are three species here. These are known in Georgetown as *Bougainvillea sanderiana*, with purple flowers (bracts), *B. lateritea*, with terra-cotta flowers, and *B. glabra*, with pink flowers. The first is the most abundant and probably the most beautiful. The red coralita (*Antigonon leptopus*) and a white variety of the same are common. The allamanda (varieties of *Allamanda cathartica*) has large yellow somewhat bell-shaped flowers. The gloriosa (*Gloriosa superba*) is a strange-looking climbing lily with spirally twisted perianth divisions. A most attractive vine is the petrea or purple wreath (*Petrea volubilis*) with long, drooping racemes of lavender or purple flowers. There is also a white variety.

The flora of the colony can best be reviewed by reference to the natural ecologic conditions. First, however, a few words may well be devoted to the introduced flora. A very large proportion of the plants found in the vicinity of the towns and the plantations is introduced. Among the grasses 20 per cent of all the known species of the colony are introduced, and since these species are found mostly around the settlements, they would constitute there a much greater proportion. Comparing the grass flora of Georgetown with that of the West Indies, one is surprised at the absence or rarity of certain species commonly introduced in the latter region. Among these may be mentioned *Eragrostis ciliaris*, *E. pilosa*, *Dactyloctenium aegyptium*, *Chloris ciliata*, *C. paraguayensis*, *C. petraea*, *C. radiata*,

Nazia aliena, *Antheophora hermaphrodita*, *Valota insularis*, *Paspalum paniculatum*, *Panicum fasciculatum*, *Cenchrus viridis*, *Manisuris granularis*. All these species are common weeds in the West Indies.

The mangrove formation is conspicuous along nearly the whole of the coast of British Guiana and extends along the banks of the rivers as far as the influence of salt water reaches. The tide is felt many miles inland, usually as far as the first rapids, that is, from 30 to 60 miles, though the salt water may not reach this far. Salt-water plants are found in places where the surface water is fresh. It is probable that in such places the lower layers of salt or brackish water are overlain with fresh water. The chief species of trees making up the mangrove formation are black mangrove (*Rhizophora mangle*), white mangrove (*Laguncularia racemosa*), courida (*Avicennia nitida*), and bindoree (*Drepanocarpus lunatus*). The black mangrove has glossy thick dark green leaves. The seeds germinate while still attached to the branches and the root extends down as a cylindrical brown object several inches long, looking like long pods. These finally fall off and the young plant falls into the mud or is carried by currents till it is stranded and then continues growth. The roots of the tree are arched and stilt-like, forming a tangled mass through which the tide rises and falls. The black mangrove appears to be more common along river banks than along the sea coast.

The white mangrove has smooth leaves and white pubescent spikes of flowers, the hard nutlike fruits obovate and two-ridged. The courida has the leaves whitened beneath and produces large numbers of vertical air roots that come up through the soil in the vicinity of the plants. The bindoree or bindoree pimpler is a vicious plant because of the numerous short firm recurved stipular prickles. This species belongs to the legume family and has racemes of rather small blue papilionaceous flowers and flat curved or lunate pods.

On a sand flat near Kitty Village, a suburb of Georgetown, may be seen several characteristic shore plants. A creeping morning glory (*Ipomoea pes-caprae*) with upright flowering stems a foot or two tall is abundant. Other common species are a kind of salt grass (*Sporobolus virginicus*), seashore heliotrope (*Heliotropium curassavicum*), with one-sided curved racemes of small white flowers, sea purslane (*Sesuvium portulacastrum*), with spreading or creeping fleshy stems and pink star-shaped flowers in the axils of the leaves, salt-wort (*Batis maritima*), a semishrub a foot or two high growing in the mud around the mangroves, and love vine or dodder (*Cuscuta* sp.), a yellow leafless vine parasitic on the sea purslane.

The coastal region, the alluvial plain extending several miles back from the coast, is to a considerable degree occupied by marshes. On

account of the heavy rainfall the water is fresh except near tidal estuaries where it is more or less brackish. The marshes are interspersed with rivers and creeks, and water plants are abundant. The most characteristic tree of this region is the eta palm (*Mauritia flexuosa*) which gives the marshes the aspect of the low land along the coast of South Carolina where the cabbage palmetto (*Sabal palmetto*) is the prevailing tree. The eta palm has a cluster of deeply cut fan-shaped leaves.

A common plant in the marshes and along the streams is muckamucka (*Montrichardia arborescens*), an erect aroid growing to the height of 10 to 15 feet, gregarious in dense impenetrable thickets. The stem is thicker at the base and covered with short straight prickles. The white flowers are about the shape of those of the calla lily. A great variety of water plants are found here, many of them with showy flowers, and many species of sedges and grasses. The giant *Victoria regia* is native to the rivers farther inland but is freely planted in the canals of the botanical garden and other parts of Georgetown. The immense leaves are several feet in diameter and are turned up at the edges. Several species of water lilies are found, some native, some introduced, with flowers white, yellow, pink, and blue. The water hyacinth (two species of *Eichornia* or *Piaropus*) with a showy cluster of lavender evanescent flowers and the leaves swollen and hollow at the base, several species of *Utricularia* and *Pinguicula*, water lettuce (*Pistia stratiodes*), *Cabomba*, *Salvinia*, *Azolla*, and *Mayaca*, are frequent.

Somewhat farther up the rivers is found the wild cacao (*Pachira aquatica*), with digitate leaves, large tassel-like flowers as much as 8 inches long, and brown fruit about the shape of a cacao pod.

When a clearing is allowed to grow up to forest one of the first species to make its appearance in quantity is the trumpet tree (*Cecropia peltata*).

The virgin forest covers nearly the whole of British Guiana. This climax of vegetation is of great interest, for it represents the resultant of the struggle of existence between species and individuals rather than between plants and their physical environment, such as climate and soil conditions. The forest of the Tropics differs much in aspect and composition from the forest of the north. A redwood forest of the Pacific slope impresses one as being a collection of magnificent trees; the rain forest of the Tropics impresses one as being a vast amount of vegetation, but not as a collection of large trees. The edge of a forest, either where it abuts upon a clearing or where it overhangs a river, is very luxuriant, presenting to the eye an impenetrable wall of green. There is the same vigor of

growth at the top of the forest. In general, the activity of the mass of vegetation is greatest at the periphery, where there is access to light. It is here that the flowers are produced. One can usually obtain flowers from the overhanging branches of trees by collecting from a boat in the rivers and streams. One may pass through a forest and find scattered on the ground the corollas of flowers borne far above and out of sight. The collector can obtain specimens of these only by felling the trees, and he often obtains a rich harvest by accompanying workers taking out logs of commercial timber or making clearings or cutting roads or trails.

The interior of the rain forest is a solemn place. In the brightest day the sunlight does not penetrate and there is a subdued diffused light that seems to emphasize the silence. Ordinarily one can walk without much difficulty in any direction. Although there are many large trees in the forest they are scattered and the spaces between are filled with trees of varying smaller sizes. Woody vines or lianas are abundant, leafless and flowerless as they twine or struggle upwards, finally lost in the roof of the forest. Some lianas are deeply cut into the bark of the trees they entwine, others dangle unsupported for long distances, the original support having been destroyed. The trees of the first class—the giants—rise straight and strong, the shafts passing upward out of sight in the mass of branches and foliage. As viewed from the outside one sees here and there the tops of these giants rising far above the general level of the forest. Trees of a second class pass up to form the general mass of the forest roof. Between them there is a third class whose tops expand below the tops of the others and must be satisfied with a less amount of light. Below these are other classes successively more spindling, arrested in their growth by the competition of their more powerful neighbors. Some of these maintain a precarious existence, others give up the struggle and die. Dead trees, branches, and twigs soon rot away or are ground to powder by the wood ants. For this reason one never sees the accumulation of dead logs that is found in northern forests. The floor of the forest is comparatively clean. The subdued light permits but a small amount of low vegetation. There are normally a few species that have become adapted to the conditions prevailing here. Such are certain broad-leaved species of *Ichnanthus* and a few aroids and gesneraceous shrubs. There is a tendency for the larger trees to produce buttressed roots, that is, the base of the trunk expands into thin supporting slabs that radiate in all directions, giving greater stability to the tree. The mora tree (*Dimorphandra mora*), a common tree in the interior forests, has such buttresses prominently formed and often extending far up the trunk.

The species of the forest trees are not gregarious but are scattered here and there. Species of the mangrove formation are gregarious as are also such trees as the eta palm of the swampy areas.

In the region between the Demerara and Essequibo Rivers traversed by the railroad connecting Wismar and Rockstone there is a white sand scrub similar to that found in central Florida. The soil is mainly a white quartz sand. The vegetation consists of shrubs and small trees, mostly not over 12 to 15 feet tall, growing in scattered clusters or small thickets with areas of bare sand intermixed. The herbaceous plants are comparatively infrequent and inconspicuous.

In reviewing the lowland flora of British Guiana in comparison with that of the United States one notices the absence of some families, the small representation of some, and the large representation of others. The grasses, sedges, and leguminous plants are present in about the same proportion as in the United States. Some families common in the United States are absent or represented by only a few species, such as the amentiferous trees (oaks, birches, hickories), Ranunculaceae, Rosaceae, Saxifragaceae, Menthaceae (Labiatae), Scrophulariaceae, Brassicaceae (Cruciferae), and Apiaceae (Umbelliferae). The Asteraceae (Compositae) the largest family in the United States is represented by proportionately greatly reduced numbers. Some familiar families, such as Euphorbiaceae, are found in British Guiana chiefly as trees. There are arboreous species of *Solanum* with flowers very similar to those of the common white potato (*Solanum tuberosum*).

On the other hand, certain families sparsely represented in the cooler parts of the United States are found in greatly increased numbers, such as Rubiaceae, Lauraceae, and Sapotaceae. The great families Melastomaceae, Myrtaceae, Phoenicaceae (Palmae), and Piperaceae extend only into the warmer parts of the United States. Araceae, represented in the north by such puny plants as Jack-in-the-pulpit and skunk cabbage, are found as giants with leaf-blades 2 to 4 feet long or as great climbers of the forest. The orchids do not reach their greatest development in the lowlands but are a conspicuous feature of the vegetation around Roraima.

It is hoped that botanists may investigate the interior, for there is no doubt that the central and southern parts of the colony will yield many interesting discoveries.

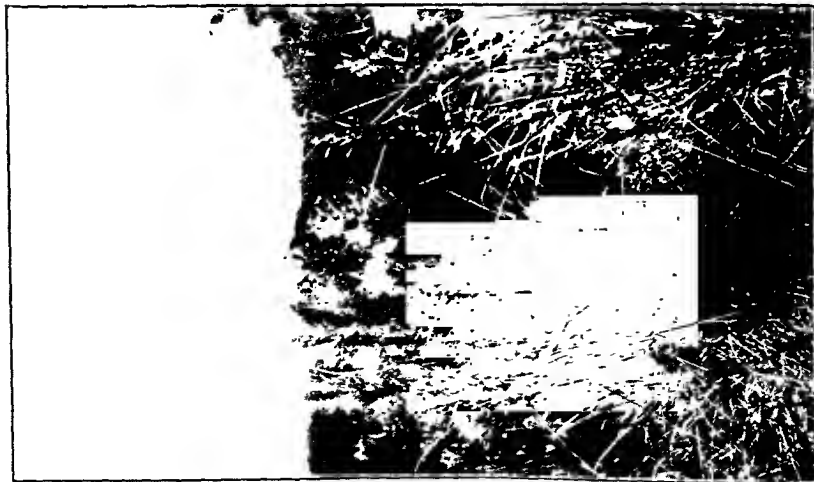




1. THE BUTTRESSED BASE OF A MORA TREE.



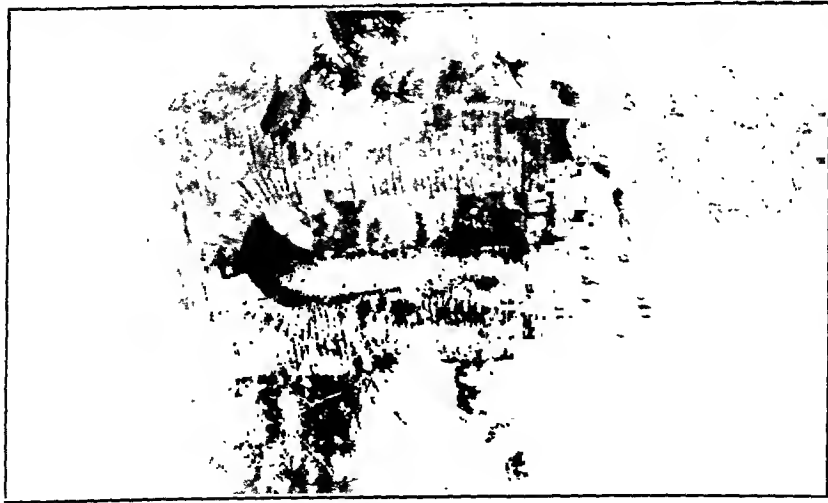
2. THE BUTTRESSED BASE OF A MORA TREE.



1. Foxtail (*Andropogon furcatus*), a common grass in the moist savannas of the coastal region.



2. A climbing plant (*Marsippospora* sp.), the leaves closely pressed to the smooth bark of a forest tree.



1. Ruins of the old fort on Kyk-over-al, an island in the Mazaruni River near Kaitabo. The Dutch settled here about 1645.



2. Travelers tree (*Borassia madagascariensis*) in the Promenade garden, Georgetown.



THE STILT-ROOTS OF MANGROVE (RHIZOPHORA MANGLE) NEAR THE PENAL SETTLEMENT.



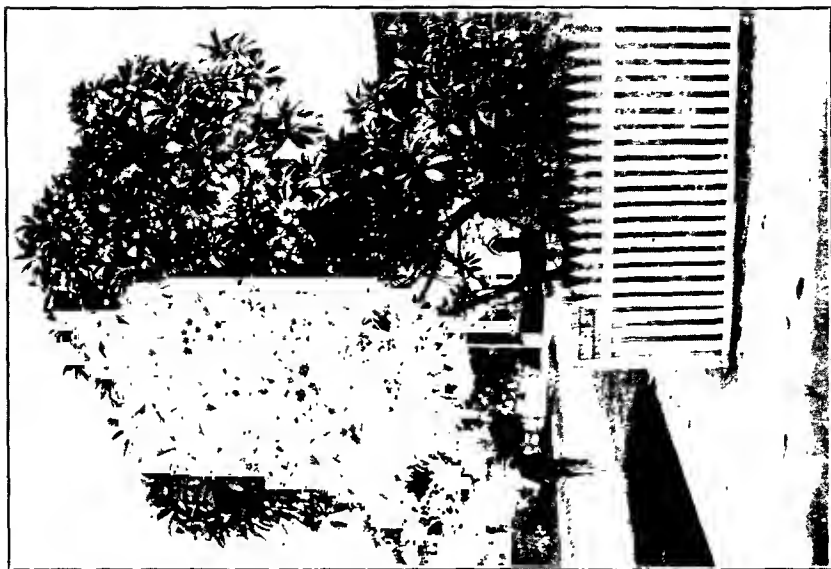
1. Bread-fruit tree (*Artocarpus incisa*). The fruits are globose, about 6 inches in diameter, greenish with a white flesh. They are boiled and used as a starchy food.



2. Flame tree (*Delonix regia*), Georgetown. The clusters of flowers are a brilliant scarlet. The tree was without leaves when the picture was taken.



1. Cabbage palm (*Oradaba olivacea*), a common ornamental tree.



2. Frangipani (*Plumeria alba*), a small tree with white flowers.



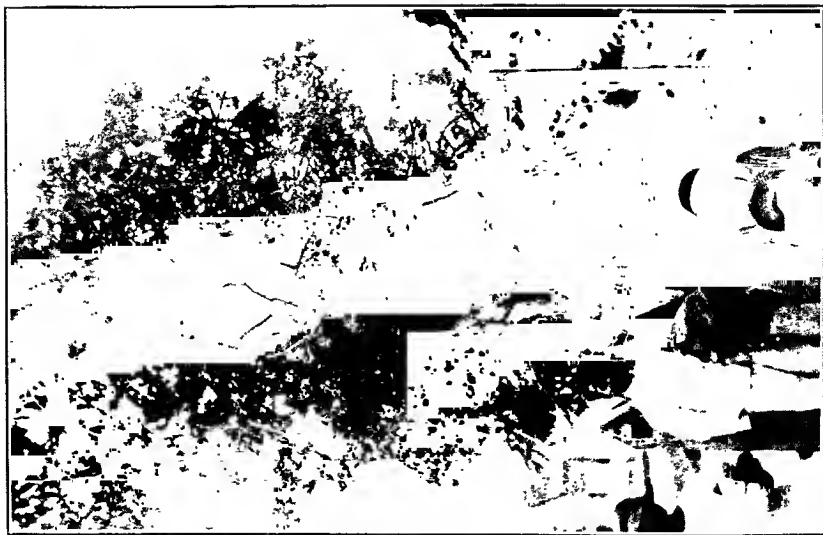
1. A cluster of papayas on Kyk-over-al. The fresh fruit of the papaya is much used in the Tropics.



2. An Indian hut near Akyma. The roof is thatched with the fronds of a native palm.



1. The cannon-hall tree (*Couroupita quinquensis*), Georgetown.



2. The cannon-hall tree, showing the flowers and fruits which are borne on the straggling branches along the trunk.



1. The eta palm (*Mauritia flexuosa*), common on the East Coast Water Conservancy.



2. The eta palm, showing the fruit.



1. The saman or rain tree (*Samanea saman*), a beautiful wide-spreading round-topped leguminous tree much grown in parks and along streets.



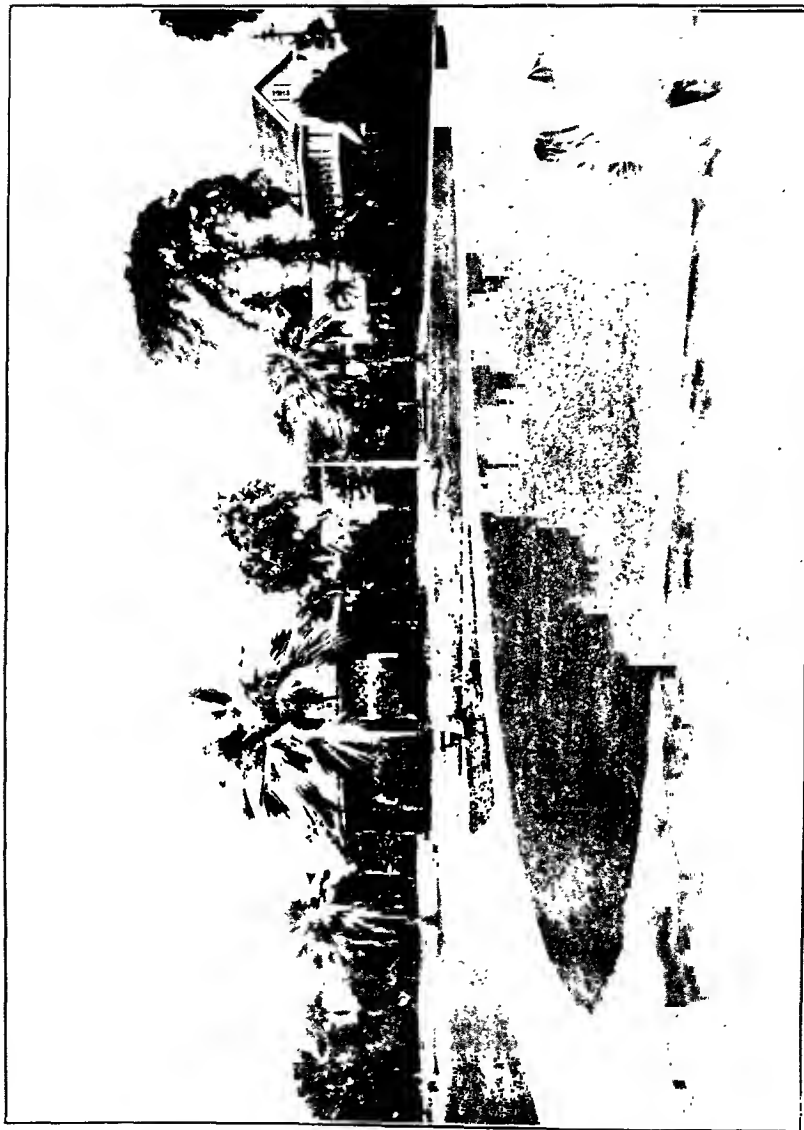
2. View from Colony House, Penal Settlement. Two cabbage palms are in the foreground, the Mazaruni River in the background.



1. A general view of the Penal Settlement. The Colony House with cabbage palms at the right



2. Bauxite at Akyma. The covering of vegetation and earth has been removed leaving the bauxite exposed. Bauxite, an oxide of aluminum, is a valuable mineral.



VIEW IN PROMENADE GARDEN, GEORGETOWN.

MILPA AGRICULTURE, A PRIMITIVE TROPICAL SYSTEM.

By O. F. COOK.

[With 15 plates.]

It is usual to write of the Tropics as a world of teeming, inexhaustible fertility, a rich storehouse of food and raw materials waiting only to be drawn upon to support the ever-growing populations and industries of temperate regions. The reality is very far from this traditional idea. Tropical lands in general are neither more fertile nor more continuously productive than those of temperate regions. Though tropical temperatures make it possible for plants to grow for 12 months in the year instead of for the short summer season of temperate countries, continuous all-year production of foods or other important crops requires specialized, intensive systems of agriculture, which as yet have been developed and applied in only a few regions.

Under the primitive system followed in most tropical countries, production not only is less continuous than in temperate regions, but may decline rapidly and even cease altogether. Regions that supported large populations and were the scenes of great activity in former times are now uncultivated. Primitive civilizations destroyed the very basis of their own existence. Nations may pass without history, and yet leave marks of devastation. Instead of the natural resources of production being still untouched, most of the tropical world is far from a virgin state, a fact too often overlooked in tropical undertakings. The woody vegetation of many tropical regions is "bush," or secondary growth, instead of original virgin forest. Very old bush approximates the original forest, but it is possible to distinguish many stages of reforestation and to estimate roughly the period that has elapsed since the land was used for agricultural purposes whether decades or centuries ago.¹

¹ See Vegetation Affected by Agriculture in Central America, Bureau of Plant Industry Bulletin 145, 1909. Other features of primitive agriculture, reforestation and domestication of plants have been treated in the following papers: Shade in Coffee Culture, U. S. Dept. of Agriculture, Div. Bot. Bul. 25, 1901; The American Origin of Agriculture, Popular Science Monthly, October, 1902; Food Plants of Ancient America, Smithsonian Report, 1903; Cotton Culture in Guatemala, U. S. Dept. of Agriculture Yearbook, 361, 1904; Change of Vegetation on South Texas Prairies, Bureau of Plant Industry Cir. 14, 1908; History of the Coconut Palm in America, Contr. U. S. National Herbarium 14, pt. 2, 1910; Wild Wheat in Palestine, Bureau Plant Industry Bul. 274, 1913; Jewish Colonization in Palestine, Popular Science Monthly, November, 1913; Possibilities of Intensive

NATURE OF THE MILPA SYSTEM.

The milpa system of agriculture is characterized by the planting of crops in temporary clearings. Instead of keeping the same land under cultivation, new clearings are cut and burned for planting, while clearings of previous years are abandoned to the wild vegetation. Doubtless the utter simplicity of the system has tended to keep it from being recognized or studied as a factor of tropical life, though of world-wide distribution. The upland cultivation of rice among the primitive tribes of tropical Asia and Africa follows the same methods as cultivation of maize in the New World Tropics. Specialized, permanent systems of terrace agriculture were developed for the culture of maize in ancient Peru and in Central America, and similar systems of terracing are used for water cultivation of rice and other aquatic crops in eastern Asia, but in both hemispheres the more advanced nations are surrounded by primitive neighbors who have continued to use the milpa system.

How little attention has been given to the relations of agriculture and tropical vegetation may be inferred from the fact that English and other European languages have had no recognized names for this primitive system of crop production which is general in hot countries, although such a term is necessary for the simplest purposes of definition and discussion. Milpa agriculture would be a convenient designation, the native word "milpa" having been adopted by the Spanish-speaking people of Central America in the sense of a maize field, or a clearing in the forest, cut and burned for planting maize. As an Aztec word, milpa is derived in Robelo's *Diccionario de Aztequismos* from "milli," a planting, and "pa," in, with the remark: "Now applied only to plantings of maize." The vocabulary of Brinton's *Maya Chronicles* includes a verb "mulba," "to congregate, to come together," the possible connection being that all the people of a community usually work together in cutting and especially in planting a milpa. "Planting-bees," as we would say, are a regular part of the system.²

Milpa agriculture appears well adapted to the needs of very primitive peoples, since only a minimum of labor and equipment is required. The ax or the cutlass is the only tool that is necessary. Tribes who did not have effective cutting implements felled or

Agriculture in Tropical America, Proc. Second Pan-American Scientific Congress, Vol. III, pp. 573-579, 1915-16; Agriculture and Native Vegetation in Peru, Jour. Wash. Acad. Sci. VI, No. 11, 1916; Staircase Farms of the Ancients, National Geographic Magazine, 39, 474, 1916; Domestication of Animals in Peru, Journal of Heredity, 10: 176, 1919; Foot-Plow Agriculture in Peru, Smithsonian Report, pp. 487-491, 1918.

²The word that corresponds to milpa in Peru and neighboring countries of South America is "chacara," but this is applied also to lands that are terraced and tilled continuously in the higher valleys. Many agricultural terms in the Quichua language seem to be derivatives or cognates of chacra, such as "chakhoni," to clear land; "chakhoska," cleared land; "chuquini," to plant seed; "chacmani," to cultivate; "chacuni," to ridge or hill the plants; and "chachuni," to irrigate.

girdled the trees by building fires around them. According to Du Pratz the Indians of Louisiana cut away the charcoal with their stone axes to hasten the action of fire in burning through the tree trunks. The method of clearing land among the Tarahumare Indians, a primitive tribe living in the mountains of northwestern Mexico, is described as follows:

On a level place in the forest where the humus is rich and generally near some stream, the Indian will take away a strip of bark 2 to 3 feet broad from the trunks of all the pine trees over a tract of a few or perhaps 20 acres or more. Then, after two or three years, the pines are, of course, completely dried up. They are now cut down and during the driest season when there, perhaps, has not been any rain for 9 to 10 months, the whole mass of trunks and broken branches are set on fire and burned to ashes. Some of the trees that stand nearest to this giant fire are, of course, destroyed, but no forest fires arise.*

Though the cutting and burning of a tract of tangled tropical forest is hard work, even with steel tools, other forms of agricultural labor are avoided by the milpa system. If a "good burn" is secured the soil is left clean and in excellent condition. Plowing, hoeing, and weeding are unnecessary. Planting still is done in Central America with a charred stick. Some of the Indians of Guatemala consider it unlucky even to walk through a corn field while the plants are growing. The ears are gathered as needed, and the stalks left standing in the field.

In typical milpa agriculture no labor is given to the working of the soil, either before or after planting. The crop simply is planted and allowed to grow. In some regions the system is varied by pulling or hoeing out weeds. The land also may be cleared once or twice with hoes or cutlasses for planting a second or a third crop before the field is abandoned to the growth of "bush." In West Africa new forest clearings are planted with rice. This ripens in a few weeks and is followed by cassava, which grows through the next season. In the so-called "jum" cultivation of Assam, forest clearings are said to be planted for two years and then abandoned for eight or nine years, while the jungle grows again. Even European settlers in the Tropics usually follow the native method of clearing the land by cutting and burning, in spite of the fact that large amounts of valuable leaf litter and humus may be destroyed. (Pl. 1, fig. 1; pl. 2, fig. 2.)

EFFECTS OF REPEATED CLEARING.

The rapid renewal of the jungle in forest clearings gives a vivid impression of exuberance that many travelers and archeologists

* See Hartmann, C. W., 1897, *The Indians of Northwestern Mexico*, *Congres International des Americanistes*, 10: 118.

have remarked, while few have taken account of the milpa system. Repeated burning of the forest for agricultural purposes produces an effect entirely different from the clearing for purposes of study of a group of forest-covered ruins, like those of Palenque. The woody growth is restored less rapidly after each agricultural clearing, and a state of complete denudation and exhaustion of the soil may be reached if the burnings continue. A region that has been exploited thoroughly by the milpa system may require many decades, and even centuries, before the fertility of the soil is fully restored.

In a virgin-forest clearing the wild vegetation may begin to reassert itself even in advance of the maturity of the crop. Sprouts may come up from the stumps or from plants with underground rootstocks that are not killed by the fire and rank weeds appear. With a moist climate and a rich soil the growth of woody plants may be sufficient in a few months to permit the same land to be burned and planted again in the second or third year, but this is true only of clearings in old or virgin forest. A longer period of renewal is required after the second burning, before there is enough "bush" to burn again, and the interval lengthens gradually to the fifth, seventh, or tenth year, depending upon the soil and other local conditions, but also very largely upon the length of time that the district has been occupied since the original forest growth was destroyed.

That the "bush" takes longer to renew itself after each successive cutting and burning means, of course, that the soil is becoming less fertile. The genuine forest growth gives place to other plants that are adapted to the more open and exposed conditions of the burnt-over lands, and eventually some of the large perennial grasses become established. Though grass burns readily in the dry season, the roots and rootstocks are not injured and continue to occupy the soil to the exclusion of other plants. The method of cutting and burning serves to clear land of woody vegetation, but becomes ineffective when the land is occupied with grasses that resist fire. Accumulations of dry grass make fires hot enough to destroy seedlings of other plants, or even to kill large trees when the heat is carried by wind.

The self-limiting character of milpa agriculture does not result solely from burning the clearings that have been cut for planting, but also from the fire spreading to neighboring bush or grass lands. Where only 5 or 10 acres have been cut 100 or 1,000 acres may be burned over. The Tarahumare Indians, of northwestern Mexico, according to Hartmann, keep up a custom of burning off all the grass during the dry season from April to June in the belief that the smoke clouds produce rain, "wherefore it becomes almost impossible to travel in the mountains during that time of the year, there being no

pasture to be found for the saddle and pack animals. Fires are seen continually burning day and night all over the mountains up to the highest crest, leaving the stony ground blackened and barren, but the forests stand green."

With fires sweeping over the country at intervals of a year or two, the grasslands not only are maintained but may even encroach upon adjacent tracts of woody vegetation from the windward side. The wider the area of grasslands the more they tend to increase through the agency of fire, until the whole district is denuded, or forests remain only in places that are inaccessible to fire because grass does not grow, as on rocks, loose sand, or flooded areas along the streams. When the process of denudation has gone so far that land for milpas can no longer be cleared and planted by the native methods the period of agricultural occupation is at an end. Thus the milpa system carries with it the agency of its own destruction in producing the grasslands that are not amenable to the kind of cultivation that the system provides, and the process tends to accelerate as the limit is approached. As long as a district is occupied by an agricultural population using the milpa system the danger of fire remains.

The regular use of grasslands for agricultural purposes is confined to temperate regions and to high altitudes in the Tropics. Plowing or some equivalent operation must be performed in order to uproot, bury, or otherwise destroy the grasses before crops can be planted. But plows and harrows are worked with draft animals, which primitive tribes do not have.

Grasslands are subdued by hand labor in a few overpopulated tropical regions. A nearly continuous cultivation is maintained in some of the mountain districts of Haiti where grass and weeds are dug out with cutlasses. The result is a more rapid and complete denudation of the land, and a restricted production of food must be expected if better systems are not introduced. Another result is heavier floods and land slides that destroy agricultural lands in the lower valleys. (Pl. 13, fig. 2.)

A more primitive and yet distinctly specialized system of cultivation of grasslands is reported by Chalmers and Gill among the natives of southeastern New Guinea.

The plantations are well cared for. We came upon a number of men in the bush preparing the soil for planting. The long grass had been burnt off. Now, for the digging up of the hard ground. Several men stood in a row, each provided with a sharp-pointed strong stake. These are driven into the soil in unison; in another second the hard clods are flying upward all along the line, reminding one of the perfect regularity with which a man-of-war's crew dig into the water. These men went on with their employment without paying the slightest heed to us strangers.⁴

⁴ Chalmers, J., and Gill, W. W., 1885, *Work and Adventure in New Guinea*, p. 295.

MIGRATION TO NEW LANDS.

The nearest approaches to plowing by native methods in America were made in Peru and in Central America, but in both regions tillage agriculture appears to have been confined to the high plateaus, and is not known to have extended to the tropical lowlands. Most of the natives of America had not advanced beyond the milpa stage. Except in Peru, the agricultural Indians of America had no beasts of burden, and even the llama was not used as a draft animal to assist in the cultivation of the land. The permanent terrace agriculture of the maize belt of Peru and the still more laborious turf-land cultivation of the high-altitude potato belt are examples of specialized systems that replaced milpa agriculture in limited areas. Tillage and the use of fertilizers were regularly practiced in Peru, as well as the reclamation of arid valleys by irrigation through long canals very difficult to construct in precipitous mountain valleys. Large areas of permanently productive artificial lands were made by terracing, filling, and covering the surface with a thick layer of fertile soil. The terrace system was applied both to steep slopes and to the bottoms of the valleys, with the stream beds straightened, narrowed, and walled in.

Instead of improving their methods and making their agriculture more intensive by tillage, cultivation, guano, irrigation, and terracing, as practiced in ancient Peru, the Indians of Central America used the milpa system more extensively, and this plan is still followed. People who have exhausted neighboring lands go farther out until they find good soil for milpas, sometimes 50 miles or more from their ancestral villages, and carry the crops home on their backs. More traveling is done instead of more farm labor, and the people are inured to the carrying of heavy loads, in which they show remarkable strength and endurance. To bring in the harvest from the distant milpa may require several trips by the whole family. Forty man loads of maize were considered as a normal supply for a family, according to Bishop Landa, who wrote of the Mayas of Yucatan about 1566. The mecapal, a woven band or strip of leather across the forehead to support the load on the back, is a characteristic feature of this long-distance milpa agriculture. Even a young child wears his little mecapal and carries a small bag of corn.

Although agriculture is always considered a settled existence, in comparison with hunting or pastoral life, milpa agriculture is in a sense nomadic, from the need of moving about in order to find lands suitable for planting. Like wandering shepherds, the same tribe might come back after decades or centuries to reoccupy a region that their forefathers had deforested and abandoned. Thus a succession of agricultural occupations is indicated in some districts in Central

America, corresponding to the native traditions of tribal wanderings for many centuries before the arrival of Europeans. Though the dated inscriptions that archeologists have deciphered on the statues and monuments of Central America go back only a little beyond the Christian era, the Mayas had an exact system of chronology with a starting point about 4,500 years before the Spanish conquest.

LIMITS OF POPULATION UNDER THE MILPA SYSTEM.

Only a small, scattered population can secure permanent support from the milpa system of agriculture. As any particular piece of land can be expected to produce crops of corn only at intervals of several years, each family requires a large acreage. Among the coffee planters of eastern Guatemala, in a forested mountain country with many fertile valleys, the carrying capacity of the land for Indian laborers is estimated on the basis of 100 to 200 acres per family. In a partially denuded or improverished country even five hundred or a thousand acres per family might be required for a permanent food supply.

The natives of West Africa always prefer to cut the "big bush," knowing that the forest soil is more fertile. "Young bush" is cut when older growth is not accessible. The zone of grass-covered "old fields" around an African village is continually widened, and when there is no more forest within reach the village is moved to an unoccupied district, if such can be found. The grassy "fields" persist long after the other signs of human habitation have disappeared.

The same preference for the new clearings in old forest is found among the natives of lowland districts in Central America, but in the mountains of eastern Guatemala the first crop of maize after an old forest has been cut may not be as large as the next crop on the same land, when it is cleared again after the first period of secondary growth. In the rainy climate of the mountain districts it may not be easy to get a "good burn" sufficient to kill the tree roots and clear ground thoroughly. In some seasons the brush remains too wet to burn and then there is danger of famine. Not to lose a possible chance that dry weather may come late in the season the Indians plant their milpas and burn them afterward, if possible. In moist ground the seeds or young seedlings are not killed by the fire sweeping over them, but usually only a partial crop is secured by this expedient, even where the maize is cared for by weeding and cutting out the tree sprouts. In wet years the coffee planters find it necessary to import maize from New Orleans to feed the native population, though the Indians still suffer because the tortillas made from the foreign grain are bitter and unwholesome, quite different from the excellent native product.

Such years of famine would tend naturally to keep a primitive people from occupying a very humid district unless driven by pressure of population or other necessity, or unless there were a system of storehouses for feeding the people in famine years, as in ancient Peru. The chief danger in Peru was from unseasonable frosts in the high altitudes, but at ordinary elevations either too much rain or too little would represent a limiting factor, tending to destroy or drive out a primitive people that had ventured beyond the margin of a safe existence or depleted the resources of its native district.

If the population remains in a district after all the lands have been cut over, resort must be had to repeated clearing of the same lands as soon as the "bush" is large enough to burn, without waiting for trees to grow and new soil to be formed. And since the forest growth and the fertility of the soil are renewed more slowly after each burning, the adverse effects tend to be multiplied. Once the balance is upset, so that the natural agencies for renewal of the soil do not have time to work, milpa agriculture becomes an actively destructive system. How often the land may be cleared, or how many times the woody growth will renew itself, must be determined by the local conditions of soil and climate, but a definite limit is reached when the woody vegetation ceases to grow and the land becomes occupied by grasses. The larger the population the more complete and extensive is the agricultural catastrophe which must ensue when a people who depend entirely upon the milpa system have exhausted their resources of production.

CENTERS OF POPULATION.

Primitive tropical peoples may live either in villages or large communal houses or the families may be widely scattered over the land. Even among the Maya peoples of Central America there were tribes like the Kekchis of eastern Guatemala who seem originally to have had no villages until assembled by the Spanish missionaries for religious control and instruction. The fact that all the so-called "Old Empire" cities of the Mayas in Central America have been found buried in deep forests shows what the country was like before it was occupied by the builders of the ruins. But wide areas of the Maya country must have been cleared when there were people to build such cities.

The more centralized a population becomes the more definite and obvious are the effects of its agricultural activities. The lands immediately surrounding large Indian towns in Central America at the present time are not merely deforested after the manner of clearings for milpas, but are completely denuded, in order to furnish fuel for the towns. Firewood and charcoal for many of the towns are

carried on the backs of men for 2 or 3 leagues, and sometimes for much greater distances. Lands suitable for farming have to be sought much farther away, often at a range of 20 or 30 miles. Indians from San Pedro Carcha near Coban may plant milpas in the district between Senahu and Cajabon and carry corn home on their backs, 50 or 60 miles.

The tendency is, of course, for people who raise their crops too many miles from the home settlement to spend more time at their milpas and carry back less of their corn. Thus an old center is likely to lose its population gradually after the circle of exhausted land becomes too wide, or the people may migrate together to a new district. Native villages in West Africa usually occupy the same site for only a decade or two. With nothing in the way of permanent buildings or other improvements to interfere, a new location is sought as soon as all the forest has been cut within a convenient radius of 2 or 3 miles. Much larger areas of denudation were formed, no doubt, by people who advanced further in civilization and made permanent investments of labor in the building of stone houses, temples, and monuments, as in Central America. But considering that there were no beasts of burden in Central America, and very little in the way of navigable rivers, so that transportation was limited to human carriers, centers of population could hardly have been maintained from lands that were more than 20 or 30 miles away. Some families might go farther out to "make milpas" and carry in their corn, so as to live in town for a part of the time, but large centers would be impracticable on a basis of milpa agriculture and man-back transportation.

In other parts of the world where beasts of burden were used, boats on rivers, or ships on the sea, supplies could be drawn from greater distances, hundreds of miles, if necessary, so that larger and more permanent centers of population could be supported, like the ancient cities of the Babylonians, Egyptians, Greeks, and Romans. Agricultural decay and reduced production at home were made good temporarily by extending the range of commerce, but with ever-increasing difficulty and eventually disaster.

The general tendency of civilization is to develop large centers of population without corresponding improvement of food supplies, so that practical limits are reached. Urban ideas and interests are dominant, industrial and commercial activities are preferred, and agriculture remains in the background. As more people are drawn into cities, supplies have to be brought from greater distances, requiring more labor and more complex and delicate economic adjustments.

With the arts of transportation still more improved, our modern centers of industrial activity have the entire world in tribute and are

dependent upon the agriculture of people who live thousands of miles away, on other sides of the globe. Facilities of communication make the agricultural problem universal, though production still is limited by the same factors as in primitive times. Forests and soils continue to be depleted. Production is not maintained indefinitely on the same lands, but new regions are opened and exploited. Our agriculture must still be described as predatory and temporary, rather than as constructive and permanent. Unnecessary transportation wastes labor and other productive resources in civilized countries no less than among the primitive people who find themselves compelled to move to new lands when old locations become denuded and grass-grown.

The removal of population from a denuded district might be gradual, or there might be a general withdrawal to a new settlement in the midst of fertile lands and with an abundance of fuel close at hand. Thus it is not difficult to understand that a center of population in one period might a little later be completely abandoned and allowed to grow up again to forests. The Indians of Central America are extremely conservative, stationary people, who would resist any change as long as possible, but once such a movement had definitely begun the tendency would be for the whole population to go, so as to maintain a strong community. From this point of view the traditions of prehistoric migrations and colonization of new districts do not seem strange or unreasonable.

In recent centuries, during the period of exploitation by Europeans, the normal relations between the native system of agriculture and its environment have been altered in many ways. Populations have often been restricted, reduced, or compelled to move by wars, political disturbances, or economic changes, and the agricultural systems of many districts have been altered profoundly by the introduction of beasts of burden and grazing animals. Grass lands that were useless before became available as pastures. (See pl. 13, fig. 1.) In some districts grazing may reduce fires and thus assist reforestation, but in the tablelands of Guatemala the danger of erosion seems to have been increased by close grazing. (See pl. 12.)

PRECAUTIONS AGAINST THE SPREAD OF FIRES.

Primitive peoples would hardly be aware of the limitations of the milpa system or make conscious efforts to maintain a balance with the natural conditions to insure a food supply for future generations. Within its own sphere of influence each family chooses annually the most promising place for its cornfield, with little or no regard to the outlook for subsequent years. To foresee the ultimate effects of this policy from the standpoint of the community and enforce measures

of protection implies a rather advanced state of social organization, something that might correspond to the colonizing policy of the Incas of Peru, in withdrawing people from congested districts and sending them to unoccupied regions.

A precaution observed at the present day by some of the Indians of eastern Guatemala may have been practiced more widely in ancient times. In passing through the district between Cajabon and Lanquin, in the valley of the Cajabon River, in May, 1914, when farm-burning operations were in progress, it was noticed that a method of fire protection had been applied. Many of the clearings were surrounded by barriers made by removing all the branches and dry leaves from the ground along a strip 2 or 3 rods wide, which serves to stop the fire at the border of the clearing instead of allowing it to sweep over the neighboring lands.

The use of this expedient by the ancient Mayas would have enabled them to lengthen the period of agricultural occupation beyond what might have been possible under the simplest forms of milpa agriculture. According to Morley, who has deciphered the date signs on many of the ancient monuments, the period of occupation of some of the Maya cities appears to have extended over nearly four centuries, though others seem to have been inhabited for only a few decades. The nature of the soil is, of course, a primary factor in determining how long the land can be cultivated by any system of agriculture, but the making of fire-stops around the clearings of each year undoubtedly would conserve the fertility of the country and enable it to support a larger population for a longer period.

That other expedients may have been used by the ancient Mayas is hardly to be denied in the present state of knowledge. Several rather specialized systems of agriculture were developed in the neighboring mountains and plateau regions, where languages of the Maya stock are still spoken. Different forms of ancient agricultural terraces are found in several districts in Guatemala and southern Mexico, none as carefully constructed as those of Peru, but sometimes covering large areas, as in the region of Comitán and Ocosingo in southern Mexico. Terraces, with retaining walls of rather rude stonework, are found in many of the mountain valleys in eastern Guatemala, usually at altitudes of 2,000 to 3,000 feet, but some of them as low as 700 feet. In the eastern valleys of Peru most of the terraces are at altitudes between 12,000 and 6,000 feet, with little or no terracing below 5,000 feet.

Though the agricultural period might be lengthened for several generations by using the fire-stops, the natural limitations of the milpa system would be reached eventually. Population would need to be restricted as well as fires if a permanent balance were to be

maintained. More people would mean greater pressure for frequent clearing and planting of the land. Areas that became too grassy for cultivation would be considered worthless, and probably would not be protected against the fire. There would be a gradual extension of the grass-covered areas and a corresponding reduction of the lands that could be cleared and planted. Even cultivated lands and slopes that have been improved by a regular system of terracing are invaded by a coarse bunch grass (*Epicampes*) in the high plateaus of Guatemala (pl. 15, fig. 2.)

PERIODS OF REFORESTATION.

After a district has been abandoned so that the woody vegetation is allowed to grow and grass fires become less frequent, there is a gradual return to forest conditions, though the advance of the woody vegetation into a grass-covered area is a slow process and subject to frequent setbacks as long as people remain to start fires. But even the recurrence of fires may not keep the forest from making slow, gradual gains at the expense of the grasses. Some kinds of trees have thick, nonconducting, slow-burning bark or other protection against fire, and are able to compete with the grass and finally to overcome it. The fires kill most of the young trees, but a few survive, with accidental protection of stones or ant hills. The grass is thinner around the trees and the fires gradually become less destructive. Finally, when there are enough trees to shade out the grass, genuine forest conditions are reestablished (pl. 14, fig. 2).

In many parts of Central America it is difficult to find any primeval forests or any that are old enough to represent the original condition before clearing began. The forests that are found in swamps, deserts, and rocky, precipitous places, too rough for clearing and planting by the native methods, may represent the only original growth. Even places that are difficult of access may be drawn upon for supplies of firewood or for making charcoal. That there are any large areas of truly virgin forest growth in Central America has still to be shown. Even in the rainiest districts of the eastern lowlands of Costa Rica the clearing of heavy forests for banana plantations has resulted in the discovery of abundant prehistoric remains.

During the long era of prehistoric development of agriculture and civilization in tropical America many periods of agricultural occupation may have alternated with periods of abandonment and reforestation, which would account for the presence of different kinds of ancient pottery and stonework in the same districts. (Pl. 9, fig. 1; pl. 10, fig. 1.) Though the modern Indians of eastern Guatemala are much afraid of caves, the ancient inhabitants used them generally as

burial places, if not as dwellings, and even constructed artificial caves or tumuli. Excavation of an artificial mound of earth on the Sepacuite coffee estate in a heavily forested district between Senahu and Cajabon revealed a core of rude stonework, roofed with large rocks. (Pl. 8, fig. 1.) This form of construction is entirely different from other ancient walls in the same district, which are made of thin, flat stones, not shaped artificially, though carefully laid together. The present Indians refuse to credit the idea that the walls were built by ancient inhabitants of the country and ask, "Where could anybody find so many flat stones?" Their belief is that these ancient buildings, now buried deep in the forest were the original habitations of mankind, prepared in advance by the Creator, "When man was born, when daylight broke over the earth."

The time needed to complete the process of reforestation in a district that has been denuded must depend, as in denudation, very largely upon the local conditions of climate, soil, and topography. Several decades are required for the growth and production of seed by the pioneer individuals, the pines, oaks, or other fire-resistant types, the first invaders of the grasslands, and other decades for the more abundant trees that must develop before the growth becomes dense enough to exterminate the grass and permit the succession of genuine forest types to begin. Many kinds of trees that are abundant in the new forests, such as *Cecropia*, *Castilla*, *Heliocarpus*, *Ochroma*, and *Attalea*, are only vanguard species and gradually give place to the more permanent types of slow-growing hardwood trees. Still more time is required for the flora of the undergrowth and the fauna of the humus layer of the soil to be fully restored after the necessary forest conditions have been established.

By taking account of the succession of types of trees and other biological features it is possible to recognize the stage of development that any particular woodland may have reached, or even to gain an idea of the approximate age of a forest. From the open grasslands to the dense tropical forest, with its slow-growing hardwood trees, is obviously a long sequence of biological events. A hundred years would be entirely insufficient, and 200 probably not enough, under the most favorable conditions. Even after 5 or 10 centuries the effects of previous denudations might still be traceable by sufficient study of a forest and what it contains.

MAIZE PLANTINGS IN UNCUT BUSH.

Another modification of the milpa system that avoids or defers the danger of grass invasion is applicable to districts that have a long dry season. It was observed in northwestern Guatemala, in the district of Nenton, Department of Huehuetenango, in May, 1906, and

seems likely to have been used more generally in former times, when steel tools were not available.

Advantage is taken of the fact that bush lands can be burned over, even without cutting, if the vegetation becomes sufficiently dry at the end of the hot season. The dead bushes and small trees that remain standing do not interfere with planting, nor with the growth of the crop. With the first rains that moisten the surface soil, the maize plants shoot up rapidly and are well grown before the surviving trees or bushes are able to put out leaves or new sprouts from the roots. As the woody vegetation is dormant at the end of the dry season, the roots are not likely to be killed and the new sprouts that are sent up during the rainy season are sufficient to shade the ground and exclude the dangerous grasses.

The hot valleys and parched lowlands where the uncut bush gets dry enough to burn are not places that would be considered very desirable for human habitation, but to avoid the labor of bush-cutting would be a very important consideration with primitive people. Probably the same system would be applicable in Yucatan, and a passage in Norman's *Rambles in Yucatan* states that burning was "the only preparation that the soil received prior to sowing it." This related to the country between Merida and Campechy, which Norman visited in April, 1842.

Though planting in uncut bush is even simpler and easier than the regular milpa agriculture, it may not be more primitive, since the method would not be applicable to original forests, but only to secondary growth. It may be significant in this connection that the southern cities of the Mayas in Honduras and Guatemala, in the regions of heavier forests, were older than the cities of Yucatan.

ARTIFICIAL GRASSLANDS AND DESERTS.

That the agricultural operations of primitive man may change completely the character of the wild vegetation and turn a dense tropical forest into an open grassland or a desert is a fact not yet appreciated adequately by students either of plant life or of human progress toward civilization. The biological considerations indicate that in its primal, prehuman condition the tropical and subtropical world had a general forest covering, and that tropical grasslands are essentially artificial.

Grasses do not exist naturally in lowland tropical forests, being intolerant of shade and unable to compete successfully with the woody vegetation. Apart from special local conditions of salty soil, periodic floods, or fires that in some regions are kindled rather frequently by lightning, there is nothing to keep the woody vegetation from invading and becoming established in any region where the rainfall is

sufficient for grasses. Trees, shrubs, and many perennial plants have deeper roots than the grasses and are more resistant under desert conditions. Many regions too dry for grasses support a growth of "scrub" or open forest. With the menace of fire removed and with time enough, the forest always becomes dominant and eventually drives out the grasses entirely, except from very rocky or broken country. The small annual grasses that spring up in the short rainy season of deserts are not to be confused with the perennial grasses of more humid regions.

PASTORAL PERIODS SECONDARY.

In view of the biological limitations of the grassland type of vegetation, wide areas of open country in tropical and subtropical regions should be considered as generally resulting from previous agricultural occupation. In the Old World as well as in the New, agricultural activity traces back to the prehistoric period, as shown by the wide distribution of agricultural terraces and megalithic stonework from the Malay region and southern Arabia to the British Isles. Pastoral Semites overran decaying oriental civilizations in early times, much as Rome was submerged in later centuries by the northern barbarians.

All through the history of China we meet with the same old tale, such as the experiences of Egypt, Syria, and Persia have made familiar, of a never-ending conflict between the desert and the sown. * * * China is the tilled land, the home of a settled agricultural and commercial people, with farms and villages and market towns, rich with cornfields, orchards, rice fields, planted with sugar cane, cotton, and mulberry, whose rivers and roads swarm with traffic and the busy competition of peaceful industry and trade. But all through their long history this people has been engaged with varying fortune in an unending struggle with the wandering, pastoral tribes beyond the borders of cultivation; * * *. These people gather as the clouds gather and burst as the clouds break in rain, but they have no enduring form or substance. From first to last they are combinations of the same wild, elemental, lawless, tent-dwelling wanderers, strong with the animal strength of a free, open-air life, who follow their flocks and herds wherever the grass is sweet and the water sufficient, but never settle down in fixed habitations anywhere to learn habits of industry * * *.

In the opening chapters of the Dawn of History, Myers also has gone further than most historians in recognizing that higher types of agriculture or of civilization are not likely to have been developed by pastoral peoples, but does not consider that the pastoral state may be a secondary development, consequent upon the formation of grasslands and the domestication of animals in earlier agricultural periods. Many of the regions that have been given over to the nomads in historic times are known to have been the seats of former agricultural

* Clennell, W. J., 1917, *The Historical Development of Religion in China*, pp. 161-163.

populations. The rich, luxuriant grasslands of the Russian steppes, the prairies of our Western States, the South American pampas, and the open country of tropical Africa probably do not represent original conditions.*

It seems more likely that the first domestication of animals was accomplished by settled agricultural people like the Peruvians or the ancient Egyptians and Chaldeans of the Old World than that wandering herdsmen should have begun the cultivation of plants. Pastoral habits have been adopted in recent centuries by tribes of Indians both in North and in South America, using domesticated animals brought by settlers from Europe. Among our western Indians horses, cattle, goats, sheep, pigs, and chickens have been adopted before taking up the culture of wheat or other European plants, the reason being no doubt that crops require more labor than the herding of animals. In the highlands of Guatemala, as among the Navahos of New Mexico, many thousands of sheep are kept by the Indians, and wool is spun and woven by primitive native methods that were applied in former times to cotton. With horses to ride some tribes that had lived previously by agriculture adopted a still more nomadic existence, following the buffalo herds.

Before the arrival of Europeans animal husbandry was practiced in America only in the southern Andes, by the people who had the most specialized and intensive systems of irrigation and terrace agriculture, as well as the largest series of cultivated plants. (Pl. 7, fig. 1.) The Peruvian agriculture covered the entire range of production from tropical eastern valleys to the upper limits of potatoes and other Andean crops, which are grown in some valleys at altitudes of more than 14,000 feet. But still higher slopes and plateau districts are denuded and grass grown, and there the flocks of llamas and alpacas are tended and sheared, like sheep and long-haired goats in Mediterranean countries, with the male llamas serving also as beasts of burden, like camels or donkeys.

In thus combining animal industry with irrigation and terrace farming the agriculture of the ancient Peruvians was closely parallel to that of the early dynastic period of Egypt, and to the system introduced by the Sumerians into the Persian Gulf region. In America many stages of development can be traced, leading up to the Peruvian agriculture, whereas in the ancient seats of Old World civilization agriculture appears abruptly, with no provenience recognized. If Egypt and Chaldea represent the beginnings, as usually supposed, agriculture in the Old World would seem to have reached all at once the highest, most specialized stage of development, with-

* Busse, W., 1908, *Die Periodischen Grasbraende im Tropischen Afrika, ihr Einfluss auf die Vegetation und ihre Bedeutung fuer die Landeskultur*, Mitthl. aus den Deutschen Schutzgebieten, 21: 2.

out passing through the stages represented by the more primitive agricultural civilizations of tropical America.

But the effects of agriculture can be considered apart from the question of origin. Budge, Breasted, and other archeologists now recognize that originally the Nile Valley, with its annual floods, was a succession of well-nigh tropical jungles and swamps, inhabited by elephants, hippopotami, and crocodiles, and the Valley of the Euphrates seems not less likely to have been wooded. Certainly southern Arabia and Palestine were not naturally treeless, nor other countries around the Mediterranean. Since the milpa method of cutting and burning is the only way of clearing woodland for agricultural purposes among primitive people, it may be supposed to have been used in western Asia and the Mediterranean region, as in other parts of the world, until the forests were exterminated. A chronic scarcity of timber in Mediterranean countries during the historical period may be considered as a normal consequence of earlier agricultural occupation, in the prehistoric age.

PERMANENT AND TEMPORARY SYSTEMS.

Milpa agriculture as a system stands as in contrast with tillage agriculture, in which plows or other implements are used to break the land before planting and crops are cultivated during the period of growth. From our standpoint of familiarity with tillage methods the milpa system appears not only temporary but highly destructive and self-limiting, since the growth of grasses may render the land useless in a few decades. Even the best land can be used only at intervals, as long as dependence is placed entirely on fire as a means of clearing the soil for planting. With milpa agriculture the question of permanence hinges entirely on whether there are many people or only a few. Milpa agriculture is a permanent system if the intervals between successive clearings of the same land are very long and the forest has time to restore the soil to its original condition. A few people can live indefinitely in the same region, but limits are reached as civilization advances.

The essential inferiority of the milpa system lies not so much in its lack of permanence, since this would be secured if a proper balance of the population were maintained, but in the fact that the carrying capacity of any region must remain very small, only a fifth to a tenth part of the land being planted at the same time, even with a well-organized milpa system. Tillage methods have made it possible for the more progressive nations to maintain larger and more centralized populations and develop higher forms of civilization. Nevertheless, it is not to be inferred that tillage agriculture is essentially permanent, or that it is preferable to milpa agriculture

under all circumstances. Only a few regions of exceptional natural fertility afford illustrations of permanent tillage agriculture, like the slopes of Vesuvius, the Valley of the Nile, and the plain of Hauran, east of the Jordan, where a loose volcanic soil has borne rich harvests of wheat through many centuries.

Little of permanent, constructive improvement of natural conditions can be claimed except for the irrigating, terrace-building nations, and only one nation, the Japanese, has had the wisdom to maintain its forests, and yet has made great extensions of the area of cultivated lands which originally must have been very small. Tillage in most places has to be supplemented by some means of preserving or increasing the fertility of the soil, as the rice-growing nations of eastern Asia so well understand. In northern countries the keeping of domestic animals has contributed enormously to sustain crop production, but in many tropical countries the methods of temperate regions are not applicable and new adaptations are required.

Conditions are found in many tropical countries where our methods of tillage agriculture prove more destructive and less permanent than the milpa system. On steep slopes or on lands that do not resist erosion, breaking and stirring the soil may result in serious injury with the first heavy rain, or gradual surface erosion may leave nothing but a sterile subsoil after a few seasons of tillage. Thus it is possible for lands to be destroyed or seriously injured by wrong applications of tillage systems even more rapidly than by milpa agriculture. It may even be claimed that the milpa system is more permanent since it can be continued indefinitely if the cuttings and burnings are not too frequent, so that grasses do not become established in place of the woody vegetation.

The newcomer's theory of tropical development is that all of the difficulties arise from the failure to adopt the northern crops and methods. The tropical crops are unfamiliar and the lands appear uncultivated. No plows, harrows, drills, or cultivators are to be seen, perhaps only a few people, working with clumsy hoes or hacking the bushes with long knives, appearing so strange and casual that any backward condition is likely to be ascribed at once to the outlandish methods. The idea that tillage methods must be established in order to improve tropical agriculture is so nearly an obsession with people from northern countries that little consideration has been given to other possibilities, such as the intensive utilization of tree crops by methods that would maintain or increase the fertility of the soil and avoid unnecessary labor.⁷

That tree crops were not much used by primitive peoples is easy to understand when the temporary, seminomadic character of the

⁷ Possibilities of intensive Agriculture in Tropical America, Proc. Second Pan-American Scientific Congress, Vol. III, pp. 573-579 (1915-16).

milpa system is taken into account. The tree crops usually do not become productive for several seasons and require an investment of labor not likely to be made among tribes who do not have private property in land, or other assurances of permanent tenure that are the basis of agriculture in northern countries. The only tropical tree crop that seems to have been cultivated systematically and on a large scale in ancient America was cacao. The native plantations of cacao in Guatemala were compared by an early Spanish writer to the vines and olive trees of Spain. Cacao was grown as a sub-culture under leguminous trees called "mother of cacao," and the same method is still applied to cacao and coffee in many tropical countries (pl. 14, fig. 1). Instead of forming artificial grasslands and deserts, an ideal for tropical agriculture is to develop artificial forests that not only will yield food or other useful products but at the same time maintain or increase the fertility of the soil.

SUMMARY.

LIMITATIONS OF NATIVE AGRICULTURE IN CENTRAL AMERICA.

Milpa agriculture, the system that is used generally by primitive peoples in the Tropics, is based on the cutting and burning of new areas of forest each year, in order to clear the land for maize or other crops. The milpa system is adapted to sparsely inhabited regions, with long intervals between burnings, but has definite limitations in populous districts. If the land is burned over too frequently, not only the forest trees but all other types of woody vegetation eventually are exterminated. Perennial grasses become established, which render the land useless for agricultural purposes.

Replacement of all the forests of a tropical region by grasslands sets a natural limit to a period of agricultural occupation under the milpa system, because the method of clearing the land by cutting and burning is not effective against grasses. Every extension of the grass-covered areas means that more land has become unproductive, and eventually the food supply becomes restricted. A district that may have been able for a time to support a large population may be entirely denuded and completely abandoned as a fire-swept waste of grasslands. This condition continues until a period of reforestation has intervened to exterminate the grasses and renew the soil so that the land can be cleared again by burning and reoccupied by agricultural people. Many tropical forests are found to represent not truly virgin growth, but various stages of reforestation, which require a long period of time.

The limitations of the milpa system and the resulting periodicity of agricultural populations tends to be more definite in districts oc-

cupied by larger and more advanced communities, because denudation is more extensive and complete. Large Indian towns in Central America are surrounded by belts of deforested grasslands, and many districts that were centers of ancient populations are now uninhabited.

Assuming that the ancient people lived under the same conditions, grew the same crops, and used the same system of agriculture as the native populations of recent times, it is reasonable to infer that the consequences of deforestation and denudation were the same in the past as in the present, and that the same difficulties were encountered in maintaining the food supplies in populous regions. The ancient cities and sculptured monuments of Central America show that relatively large, centralized communities must have existed, and limitations of the native system of agriculture may explain why the ancient centers of population were abandoned.

To recognize the limitations of the primitive systems is not without practical bearing, in pointing to the danger of over-balanced urban activity and congestion without corresponding development of agriculture. Wider exploitation of natural resources by industrial nations is made possible by modern facilities of communication, but the biological limitations of production are to be recognized, as with the primitive milpa system. Although cultivation is more continuous where tillage methods are used, systems of agriculture that do not maintain the fertility of the soil are essentially nomadic and predatory. More permanent agriculture and more rational distribution of populations are problems to be faced. Agriculture is the root of civilization, and the plant withers if the root decays.



1. INDIANS PLANTING CORN IN A MILPA, NOT VERY WELL BURNED, IN
EASTERN GUATEMALA, CAJABON DISTRICT.



2. INDIAN CARRIERS BETWEEN TACTIC AND SALAMA.

The Indians of this region often go many miles from home to "make" milpas and their crops are carried home in back loads.



1. Remnant of old or virgin forest in the banana belt of eastern Costa Rica, a region of heavy forests and excessive rainfall, but formerly inhabited and cultivated, as shown by ancient remains found very often in the banana plantations.



2. Young coffee plantation at Sepacuite, Alta Vera Paz, Guatemala, planted among the stumps and logs after cutting and burning by the native method of agriculture.



1. DENSE TROPICAL FOREST ON SUBSTRATUM OF SOLID LIMESTONE ALONG THE RIO DULCE, EASTERN GUATEMALA.



2. TROPICAL FOREST ALONG POLOCHIC RIVER, EASTERN GUATEMALA.

Abundance of *Attalea* palms and silk cotton trees shows that the forest is not very old.



1. Milpa agriculture in eastern Guatemala, showing hillsides reforested, with a large cornfield extending along the upper slopes of the hills in the background above the town of Cajabon



2. Desert vegetation, mostly tree forms of cactus (*Cereus* and *Pereskia*) in a denuded region at El Rancho, eastern Guatemala.

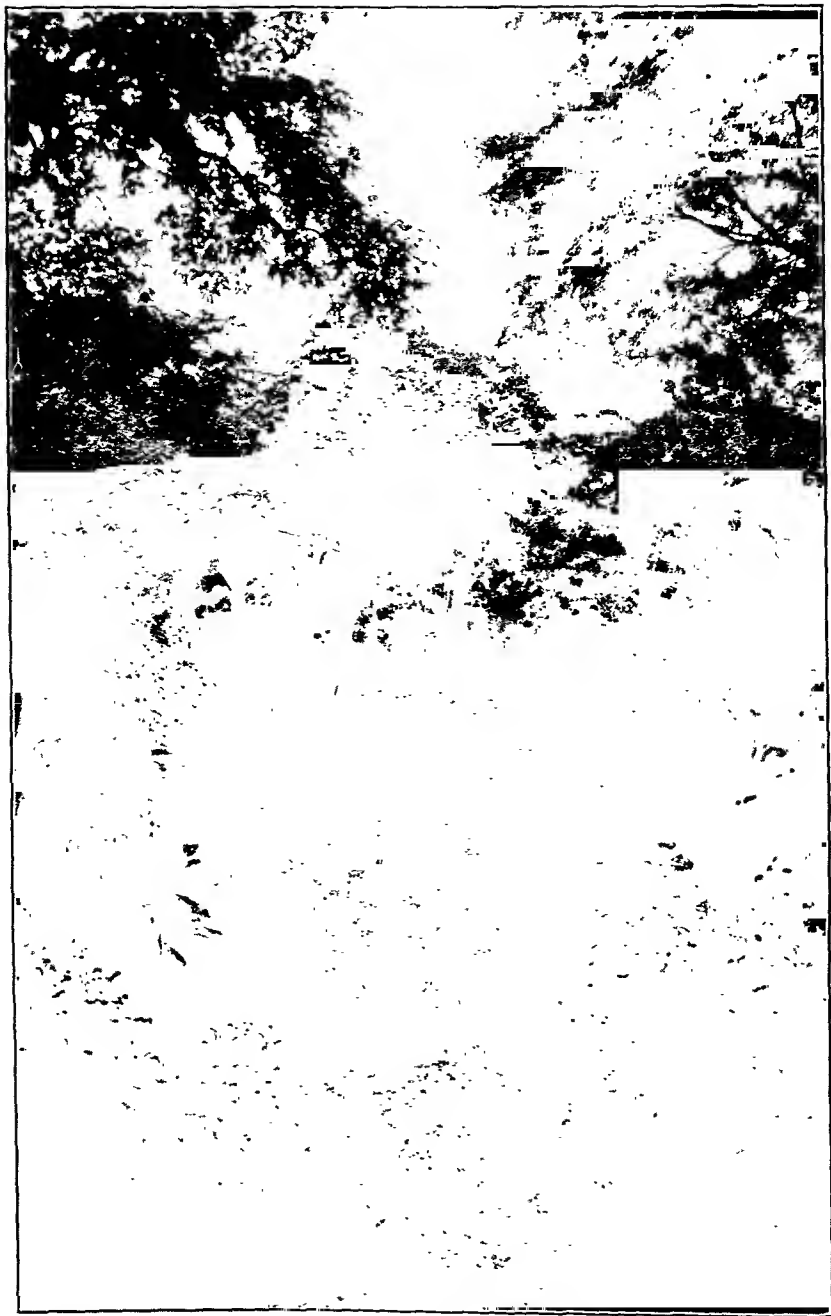


1. Milpa of the previous year, covered with low growth, on slope in background with forest above, coffee plantation, and sugar cane below, in Senahu coffee district of Alta Vera Paz, Guatemala.

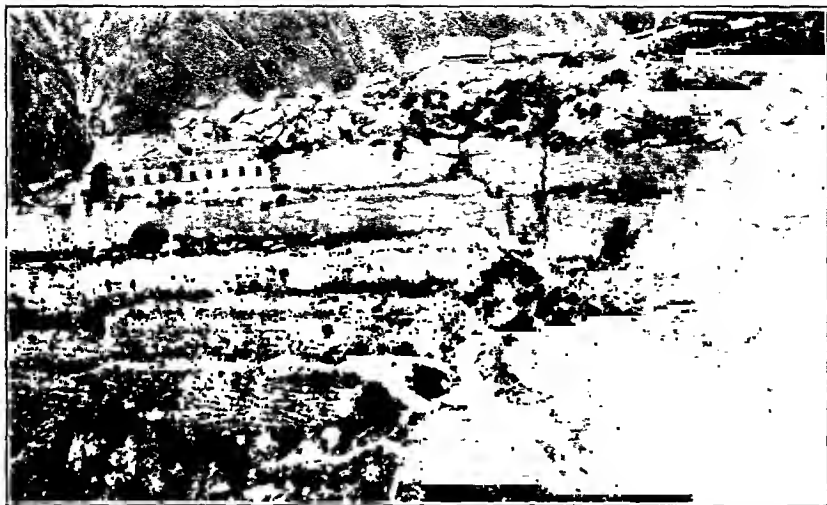


Photo by G. N. Collins and C. B. Doyl

2. Site of ruins of Mitla, showing cactus desert vegetation.



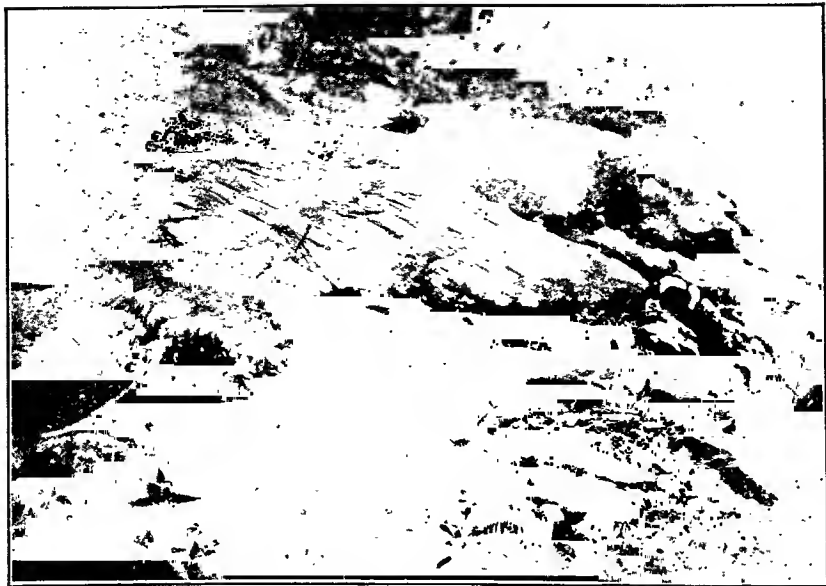
Coffee plantation near Escuintla, Guatemala, shaded by large trees to maintain artificial forest conditions



1. Prehistoric agricultural terraces at Ollantaytambo, in southern Peru, showing the most intensive and specialized development of agriculture, at the other extreme from the milpa system.



2. Ruin at Milpa overgrown with desert vegetation.



1. Prehistoric mound near Sepacante, Alta Vera Paz, Guatemala, discovered in clearing the forest for a coffee plantation. A few teeth were found, but no bones, which probably had completely decayed.



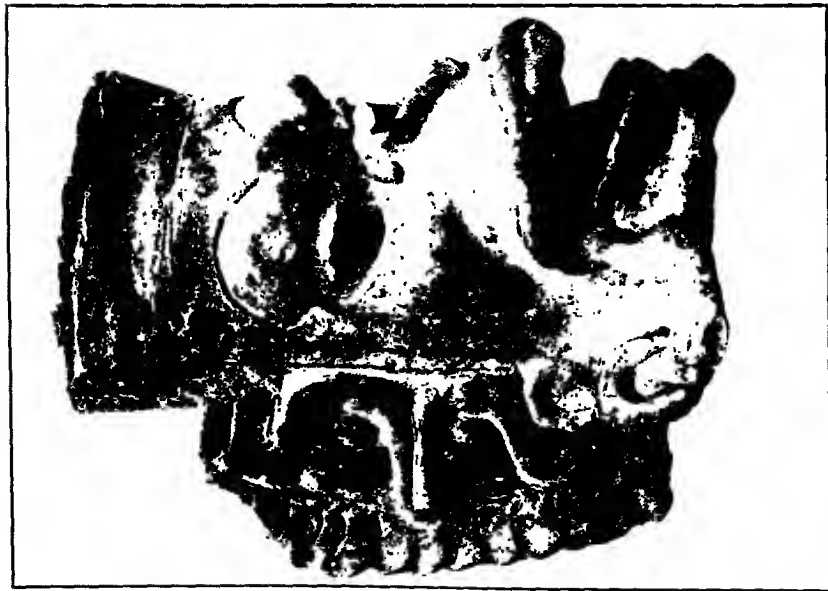
2. Milpa agriculture near Cajabon, eastern Guatemala, with growing maize on the slopes of the hills, partially reforested areas below, and recently burned milpas in the foreground, at the right a barrier or fire stop to protect the bush land above and the newly cut milpa on the slope between the fire stop and the water course.



1. Pottery bowl from a cave in the Senahu district of eastern Guatemala, relic of a previous occupation of a region now being reoccupied after a period of reforestation. The bowl measures $9\frac{1}{2}$ inches broad and 4 inches high, is of very regular form, and had an orange-yellow glazed or polished lining, still partially in place.



2. Indian cornfields in the table-lands of Guatemala, among the pyramids of ancient Quiché, originally faced with smooth stone blocks which have been removed to build the modern city. The name Quiché means forest, though no forests are left in this region.



1. Ancient pottery effigy found in recently cleared forest district, relic of an earlier period of agriculture, Sepacuite, Alta Vera Paz, eastern Guatemala.



2. Jagged limestone rocks as substratum of heavy forest growth in Cajabon District of eastern Guatemala, recently cleared by burning to plant coffee, with remaining forest in background.



HILLSIDES ALMOST COMPLETELY DENUDED AT CAJABON IN EASTERN GUATEMALA, A REGION OF HEAVY FOREST
GROWTH UNDER NATURAL CONDITIONS.



1 Gently sloping tabular lands near Quiché, Guatemala, still partly cultivated but becoming badly eroded since grazing animals were introduced.



2 Erosion of gently sloping uplands formerly cultivated near Quiché, Guatemala, with reforestation in the gullies.



1. Luxuriant guinea-grass pastures, of spontaneous growth, after burning of forest for mulpa agriculture, Gonave Island, Haiti, September, 1917.



2. Dry, stony land with too little vegetation to clear by burning, but the grass and weeds dug out with cutlasses for a scattering growth of maize, as in the background. District of Furey, Island of Haiti.



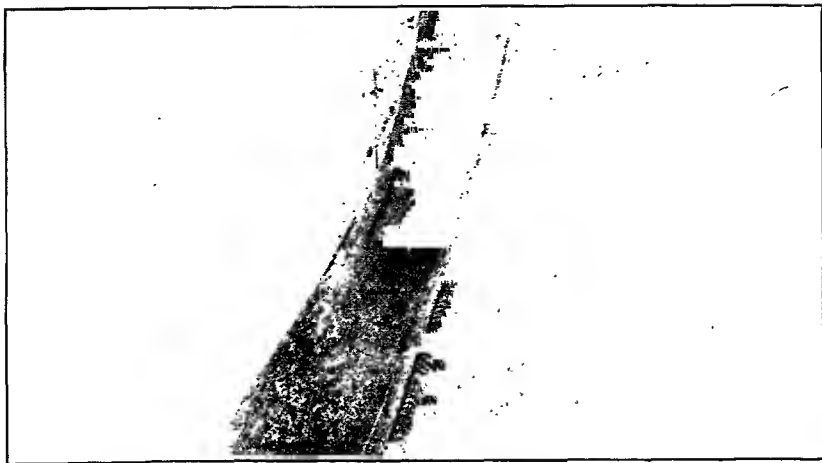
1. Plantation of cacao in Senahu district, Guatemala, an example of permanent crop production under artificial forest conditions.



2. Partially reforested grassland, Alta Vera Paz, Guatemala, slopes at the right and in the background with open growths of pine, at the left a small gully shaded by *Byrsomna* and other broad-leaved trees.



1. Creek bank, Alta Verapaz, Guatemala, showing advanced stage of reforestation with tropical growth.



2. Tertiary system of cultivation in highlands of western Guatemala, near Quezaltenango, invaded by bunch grass (*Epicampes*).

ON THE EXTINCTION OF THE MAMMOTH.¹

By H. NEUVILLE.

[With 3 plates.]

One of the most widely believed assumptions of general biology is, perhaps, that the mammoth was especially fitted to withstand severe cold. All the authors—paleontologists properly speaking, geologists, zoologists, even students of prehistory—who have had occasion to write about this witness of the earliest ages of humanity, agree on its adaptation to a cold climate. And it is surprising the weakness of the arguments which are brought forward, a weakness which is imperfectly concealed by the great word "*adaptation*" too often used, as was done in the past, with the *virtus dormitiva*, and as is still frequently done with formulas of the same kind.

On this foundation, regarded as indisputable, of the mammoth's adaptation to cold, have been developed numerous courses of reasoning, all of which are primarily concerned with reconciling this power of resistance to cold with the brutal fact that the animal which was supposed to have benefited by it disappeared, while others, placed under identical circumstances, survived.

The study of the frozen remains of mammoths found in Siberia and that of the environment in which these animals lived, remnants of which are preserved along with their own, have furnished numerous and interesting data, which are, however, less striking than the things imagined by scientists. The vegetable remains found with the mammoths throw some light on this question of environment, without, it appears, being sufficient to explain it clearly. Even with regard to this subject there is material for controversy. Howarth admitted that the fauna and flora which give this northern environment its character are mixed with Mediterranean elements whose presence complicates the problem.² Reid asserts positively that the plants found with the mammoths are not characteristic of a cold climate.³ One fact, in any event, is clear—the Siberian mammoths died in an environment which was cold enough for the remains, frozen at the time of death, to be preserved after a fashion to our day.

Admitting that these proboscideans were especially resistant to cold, it was necessary to find causes able to overcome this resistance.

¹ Translated, with permission, by Gerrit S. Miller, jr., from *L'Anthropologie*, July, 1919.

² *Geological Magazine*, vol. 8, p. 310. 1881.

³ *Geological Magazine*, vol. 8, p. 505. 1881.

The only explanation which at first sight appears satisfactory in this respect is the one offered by such writers as Cuvier and d'Archiac and brought up again by Howarth; it consists in admitting the appearance of sudden and intense cold sufficiently severe to have killed on the spot the mammoths as well as some other mammals, one of the best known of which is the *Rhinoceros tichorhinus*, and sufficiently persistent to have preserved the bodies. As this assumption of sudden glacial cataclysms rested on other arguments than the disappearance of a few animals, it resulted that the hypothesis relative to this disappearance became an essential part of a general theory regarding certain large geological phenomena of the quaternary period—transportation of bowlders, deposition of alluvial material, etc.—a theory essentially admitting a diluvial catastrophe in one or several acts, accompanied by an intense cold suddenly spread over vast areas and producing there a group of phenomena one of which would have been the brutal extinction of life, at least as concerned certain mammals.

At present no one sustains this theory, so far as I know. As to the mammoth it is admitted that, while being able, *thanks to its thick fur*, to withstand cold, the animal succumbed "because the invasion of dry cold killed off the vegetation which supported it" (de Laparent). Going somewhat further into detail, it has been admitted that the mammoth could have inhabited France, England, and Germany during the prevalence of a cold and humid climate (de Laparent's second Pleistocene age), which permitted the existence of a vegetation sufficient to feed it, but where its extinction was the work of man (Reid⁴), while in Siberia it might have been the victim of the lack of food brought on by the increase of cold, there being nothing to prove that the extinction was simultaneous in the various regions where the mammoth lived.

These explanations are not convincing.

In the first place, it is difficult to admit that the extinction of the mammoth could have been, in any region whatever, the work of man, any more, for that matter, than the work of wild beasts. Like the elephants of the present day, the mammoth could not have known really dangerous enemies among the beasts of prey; and, just as the primitive hunting methods of the African natives have never, it seems, been able to bring about the extinction of the African elephants,⁵ those of the hunters of the stone age probably never caused the extermination of the mammoth over the whole of any extensive area.

⁴ Geological Magazine, vol. 9, p. 44. 1882.

⁵ Abyssinian traditions say that the elephant has killed more men than man has ever killed elephants.

Vastly more acceptable is the hypothesis of a diminution in food supply. As Georges Pouchet says, the struggle is much more between the herbivore and the vegetation than between the carnivore and the herbivore. However, with the frozen remains of Siberian mammoths and rhinoceroses occur the traces of a relatively abundant vegetation, the presence of which Mr. de Lapparent has explained by admitting that the Siberian climate was then more humid and more oceanic, a fact for which he supplies a geographical explanation; the same author recalls, moreover, that in spite of the severity of the climate and the meagerness of the pasturage immense herds of herbivores exist on the high Tibetan plateaus. It should be noted that at that time the Siberian vegetation was arborescent up to the seventy-fourth parallel (von Toll: Liakhof Islands) and that arborescent vegetation is precisely the kind which suits proboscidiæ according to what nature now teaches us.⁶ The coincidence between a lessening of the food supply and the extinction of the mammoths therefore remains hypothetical, and the very authors who explain the latter by the former furnish arguments against their own hypothesis. A progressively aggravated stringency of food might have contributed toward the degeneration of the species, toward lessening the number of its representatives and finally to its disappearance; but it is impossible to admit, at least without falling back on the assumption of sudden cataclysms, that the mammoths allowed themselves individually to die of hunger on the icy ground which preserved their remains.

It is not exaggerated to conclude from what precedes that the question of the causes of the disappearance of the mammoth remains open, both as to the general extinction of the species and as to the very numerous individual cases in which death took place under such conditions that the corpses were immediately frozen.

It was without the idea of solving this problem that I undertook, a few years ago, the study of the integument of the mammoth. I had previously familiarized myself with the anatomical study of the elephants. The laboratory of comparative anatomy at the Paris Museum having then received a very well preserved piece of mammoth skin, I made some histological sections from this specimen. Somewhat later Mr. Boule kindly assigned to me, *pro parte*, the study of the mammoth which Count Stenbok-Fermor had just presented to the laboratory of paleontology. This was an opportunity for me to examine more closely the questions relating to the mam-

⁶ In the wild state elephants like herbage, but the staple of their diet consists of young branches and shoots; thus open forests or high brush in which they can easily move about and find their food are, with some differences between the elephants of Africa and those of Asia, the ranges that are preferred.

moth, and the readers of *L'Anthropologie* are already acquainted with the investigations which I made with Mr. Gautrelet regarding the blood of this animal.⁷

The results relating to the integument appeared to me especially instructive. They present facts which are incompatible with the generally accepted opinions regarding adaptation to cold which I have alluded to above. I shall merely recapitulate the essential points about these facts, referring, for more details, to two previously published notes.⁸

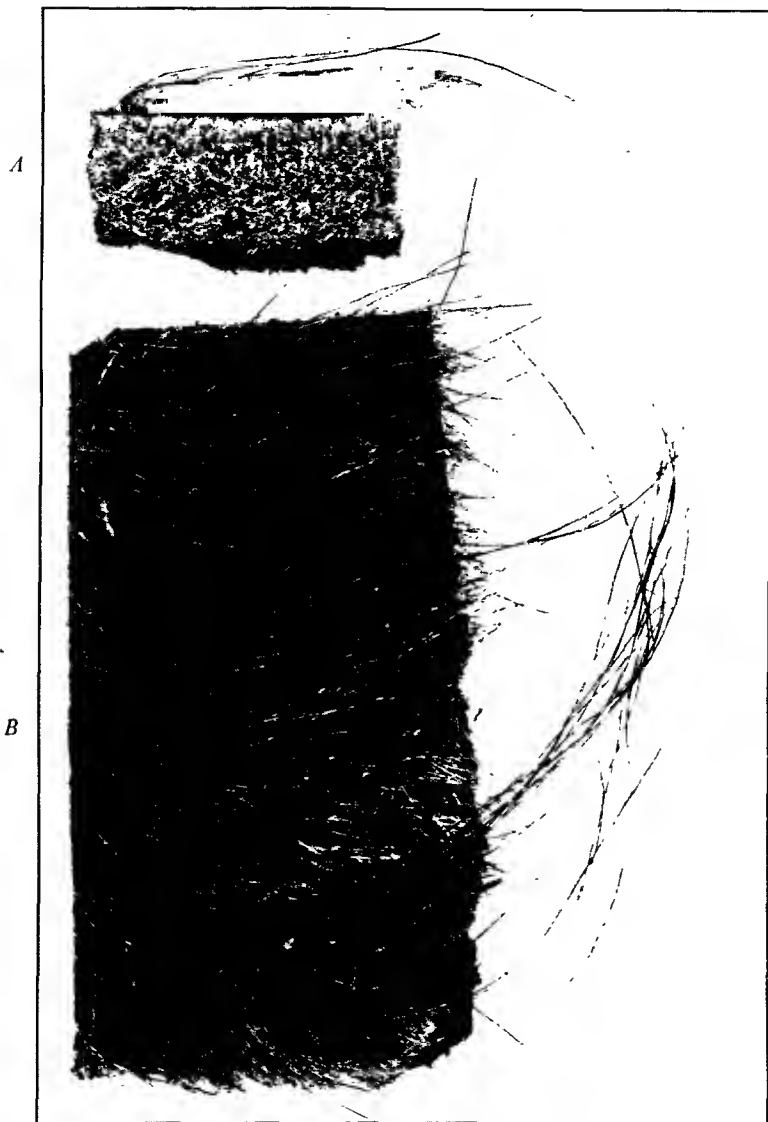
Plate 1 represents the piece of skin received by the laboratory of comparative anatomy. It is easy to distinguish two kinds of hair which I consider, without going into the discussions which have arisen relative to the distinctions to be established in the hairy covering of the mammoths, as representing merely bristles, long and scattered, and a very dense underfur. One can also see the thickness of the dermis, forming a baconlike layer.

To understand the meaning of these conditions it is necessary to compare them with those presented by the elephants which live in the tropical zone and for which there can not be any question of adaptation to cold. Plate 2 shows the essential characters of the skin of the elephants. Few hairs are to be seen; abundant on the young, which at birth is covered with a uniform down sufficiently sparse so that the grain of the skin remains easily visible, it afterwards becomes less dense simultaneously with the differentiating of the bristles and underfur. Without ever forming a thick fur, these hairs are often much more numerous on subjects living in freedom than the menagerie elephants would lead one to suppose. The dermis is here quite as thick and quite as baconlike as in the mammoths.

In the skin of the elephants, that which especially strikes the attention is the warty character of the epidermis. While the epidermis of the mammoths is almost smooth, that of the elephants, both African and Asiatic, is very coarsely rugose. The dermal papillae of these latter proboscidiens are covered with a strong epithelial coating in which the corneous layer predominates, and each papilla retains its individuality in such a way that the cutaneous covering appears shagrinous, or, rather, definitely warty; this aspect, more or less pronounced according to the regions of the body, is not yet present in the new born, in which the grain of the skin appears to be exactly like that of the mammoth, but it afterwards becomes steadily more accentuated. Plate 3 explains this structure. I have

⁷ *L'Anthropologie*, vol. 26, p. 298. 1915.

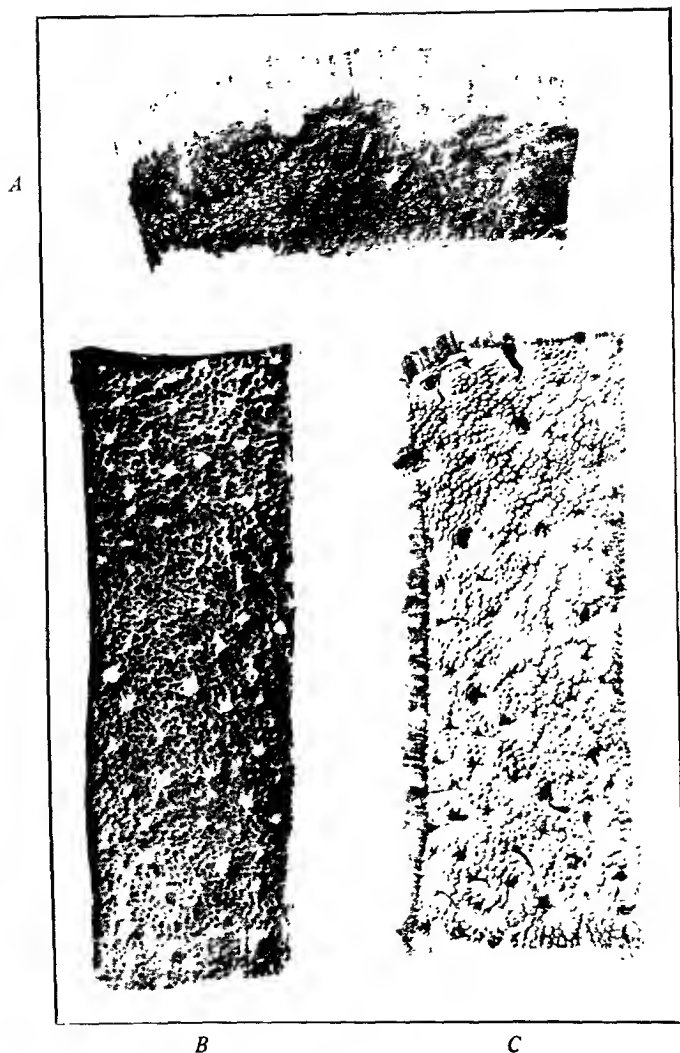
⁸ H. Neuville, *Du tégument des proboscidiens*. Bull. Mus. Hist. Nat. Paris, 1817, No. 6, and *Sur quelques particularités du tégument des éléphants et sur les comparaisons qu'elles suggèrent*. Ibid., 1918, No. 5.



PIECE OF SKIN OF MAMMOTH. NATURAL SIZE.

A. Section perpendicular to the surface.

B. Surface, showing hairy covering (bristles and underfur).



PIECE OF SKIN FROM FORE LEG OF AN INDIAN ELEPHANT.
NATURAL SIZE.

- A. Section perpendicular to the surface, showing relation of dermis to epidermis; the dermis, whitish, about 2 cm. thick, is overlaid by a blackish epidermis about 7 mm. thick, the corneous layer, formed of closely juxtaposed fingerlike masses, makes up nearly the whole of these 7 mm.
- B. Superficial aspect of the dermis after removal of the epidermis.
- C. Under surface of the epidermis.



3

SECTION OF SKIN OF FORE LEG OF AFRICAN
ELEPHANT. X10.

- c.* Hypertrophied epidermic papilla.
- p.* Papillary zone of the dermis.
- r.* Reticular zone of the dermis.
- s.* External sheath of a hair.

called attention to the nature of these facts as it appears in the light of anatomo-pathological comparisons, which alone, it seems to me, permit an understanding of its meaning; the skin of the elephant forms a vast corneous papilloma, which first appeared, according to all likelihood, as the result of the action of the irritants^{*} inherent in the environment in which the elephants live, and favored by a special character common to elephants and to the mammoth, namely, the absence of cutaneous glands. I have been no more able than earlier authors to find either sweat glands or sebaceous glands.

There is no reason to believe that the degeneration of the hairy covering in the elephants has been accompanied by or even could have been caused by the previous disappearance of the sebaceous glands, whose presence is regarded as connected, except in very rare instances, with that of the hair, so much so that these glands are even regarded as appendages to the hair. On the mammoth, as well as on the elephant, the hair occurs without its accustomed annex, the sebaceous gland, and if the hair of the present-day elephants is very sparse it was, on the contrary, as highly developed as possible in the mammoth. Hence, there is no relation here between the diminution of the hairy covering and the disappearance of the sebaceous glands. For further details on this entire question. I refer to the two notes mentioned above.

We have, therefore, two animals very nearly related zoologically—the mammoth and the elephant—one of which lived in severe climates while the other is now confined to certain parts of the Torrid Zone. The mammoth, it is said, was protected from the cold by its fur and by the thickness of its dermis. But the dermis, as I have said, and as the illustrations prove, is identical in the two instances; it would therefore be hard to attribute a specially adaptive function to the skin of the mammoth. The fur, much more dense, it is true, on the mammoths than on any of the living elephants, nevertheless is present only in a very special condition which is fundamentally

* The forehead, the anterior part of the trunk, and the lower part of the legs show this character in a specially accentuated condition. But these are the parts which are the most exposed to blows and friction against trees and brush. It is by pressing with their forehead that elephants overcome the resistance of obstacles which the trunk can not put aside; it is the anterior part of the trunk which comes the most directly in contact with the brush; as to the lower part of the legs the causes of irritation are yet more evident; finally the tail, where the papillary hypertrophy is especially strong and where it even takes on special characters, is constantly in motion and is thus subjected to irritative influences to which it reacts like the skin in general but with the acquisition of still more accentuated characters. Adaptation is here not an empty word; we know its causes, irritative influences; we can perceive its nature, keratotic reactions; we can watch the appearance of the special characters which it produces, papillomatous tendencies; we can observe its progress, graduated according to the use to which each region of the body is put and according to the influences which act on each region; finally it is easy to realize how useful to animals whose skin is fundamentally very sensitive the hypertrophy of the corneous layer can be, a hypertrophy which in other animals is pathological but which has here become normal, furnishing a protection which aids in the preservation of the species.

identical in all of these mammals. Let us examine the consequences of this special condition, consisting, I may repeat, in the absence of cutaneous glands. The physiological function of these glands is very important.¹⁰ It is superfluous to recall that the sebaceous impregnation gives the fur in general its isolating properties and imparts to each of its elements, the hairs, an impermeability, thanks to which they resist with a well-known strength all disintegrating agents, and notably those which are atmospheric. Everyone knows to what degree the presence of the grease produced by the sebaceous glands renders wool resistant and isolating, and to what degree the total lack of this fatty matter lessens the quality of woollen goods. Comparative anatomy gives, moreover, some instructive information as to the part played by this impregnation. Mammals deprived of sebaceous glands are very rare; the two-toed sloths (*Choloepus*) of Central and South America and the golden moles of Africa (*Chrysochloris*) are in this condition; but it is well known that the sloths are particularly sensitive, even in their own country, to cold and damp.

The very peculiar fur of the mammoth thus furnished only a precarious protection against cold, a protection analogous to that enjoyed at present by a few mammals of the tropical zone. Its dermis was, it is true, very thick, but no more so than that of the existing elephants. It appears to me impossible to find, in the anatomical examination of the skin and pelage, any argument in favor of adaptation to cold. It has been thought that the reduction of the ears, thick and very small relatively to those of the elephants, was the result of such an adaptation; and indeed this character might be so understood in this sense; such large and thin ears as those of our elephants would probably be very sensitive to the action of cold. But it has also been suggested that the fattiness and the peculiar form of the tail in the mammoth was an adaptive character of the same kind; however, it is to the fat-rumped sheep, animals of the hot regions, whose range extends to the center of Africa, that we must go for an analogue to this last character.

It is, therefore, only thanks to entirely superficial comparisons which do not withstand a somewhat detailed analysis, that it has been possible to regard the mammoth as adapted to the cold. On account of

¹⁰ It is merely necessary to mention that according to the opinion now accepted, that of Unna, the effect of the sebum is to lubricate the fur, thus protecting it against disintegration, and that of the sweat is to soak the epidermis with an oily liquid, protecting it also against desiccation and disintegration. In reality the deposit of sebum on the surface of the skin, so easy to observe in the human species, especially in certain cases of baldness in which it becomes excessive, contributes also to the protection of the integument. In the absence of sebum and sweat the only fatty impregnation of the epidermis is that which comes from the action of the cells of the epidermis itself; this action remains, in any event, very special and very limited, and the absence of the glandular secretions puts the skin in a condition of less resistance well known in dermatology.

the peculiar character of its pelage the animal was, on the contrary, at a disadvantage in this respect.

Still other causes of inferiority can be assigned to the mammoth. One of them is the peculiar character of the tusks. Usually very large, out of proportion even, these tusks showed most frequently, it appears, such an accentuated curve that in many individuals the tips were so directed (backward or sideways) that it is not easy to see of what use they could have been; rather than efficient weapons they appear to have been only incumbering accessories.¹¹

¹¹ Thus brought to touch upon this special subject I think that I must make a digression with regard to the use of the tusks of the proboscideans.

It has been denied that these tusks are true weapons. It has even been suggested that for the elephants they are merely a kind of tool, which the animals employ for forcing a passage through the density of the forests, and that the tips of these ever-growing teeth are worn away by this work, the normal development of the tusks being thus limited after the manner of the incisors in the rodents. According to this hypothesis it would be conceived that the excessive development of the tusks of the mammoths might result from the circumstance that these animals lived in regions where the forests were not dense enough to provide the causes of regulating wear. This argument is ingenious; however, I do not believe that it conforms with strict reality, and I ask permission of my readers to go into a few details here which by explaining the ethology of the living proboscideans will also help us to understand more clearly that of the forms which have disappeared.

The elephants wear their tusks voluntarily by rubbing them against trees for this purpose in a manner comparable to that in which cats sharpen their claws. The tusks thus sharpened (they are often quite pointed, or terminated by a kind of chisel) are very effective weapons which the elephants often use. On account of their position they can only be used most effectively against animals of about the same size as those which bear these arms, hence they serve especially, in conjunction with the trunk, in the fights which elephants engage in against each other. Elephants, especially the males, are rather pugnacious. We are thus led to regard the tusks as primarily sexual weapons, and, indeed, it is the males which are best armed. It appears to be unusual for elephants to use their tusks against creatures smaller than themselves. Of the latter, the principal, it might be said the only one with rare exceptions (carnivores attacking the young) which they have to attack is man. It is known only too well how they behave toward him—charging him, the trunk folded back between the tusks, until they are upon their hunter, now become their victim; they then seize him with the trunk, suddenly stretched out, and treading on him at the same time they crush him and in some instances they even succeed in tearing him limb from limb; it may also happen that, throwing him on the ground, they transfix him with their tusks.

Elephants sometimes use their tusks for digging superficially; I do not believe that they can use them as implements for forcing a passage through the forests. It is true that domesticated elephants use their tusks, when they are long enough, for certain tasks; for example, for beginning to raise up a beam which is lying on the ground and which they then encircle with their trunk, but it is difficult to see of what service they would be against trees. When an elephant wishes to tear away or break a shrub or a tree, if his trunk is not sufficient he applies his forehead or shoulder (especially the forehead) to the obstacle, and leaning against it with all his weight he acts upon it more efficaciously than by striking with the rather fragile tusks and running the risk of breaking them. It is well to recall also that, although inclined to wander, elephants normally, at least, follow regular paths which are not only kept clear of brush by their constant passage but which present in the dry season a remarkably leveled off appearance, stamped as they are by the broad feet of these gigantic animals. (I have in mind especially the African elephants.)

Finally it sometimes happens that elephant tusks show anomalies of curvature some of which suggest those that were shown by the mammoth; I have figured one of this kind. (M. de Rothschild et H. Neuville, *Sur une dent d'origine énigmatique*. Archives de Zoologie expérimentale, vol. 7, 1907, p. 271-333. Pl. XXII-XXIV.) In the mammoths anomaly tended to become the rule, and this perhaps because of the absence or rarity of trees large enough to serve for the wearing down process which I have described above. But from this last argument we can not deduce any proof as to the character of the vegetation; it is asserted that the Siberian mammoths lived in the midst of trees of a fairly large size, birches for instance, and a few traces may sometimes be seen on their

Others are characters which I believe to be imperfectly known up to the present and which I am going to mention briefly. If the mammoth did not show the keratotic reactions which give to the epidermis of the living elephants its truly characteristic warty structure, the skin seems none the less to have undergone some reactions of the same nature, which were, it is true, strictly localized, and which instead of constituting an adaptation—that is, instead of being of utility—were to the highest degree inadapative. Tilesius had already observed in the mammoth of the St. Petersburg Museum that the soles of the hind feet appeared “as though dilated and crushed by the weight of the body so that they came up over the edges of the feet and covered them,” and Cuvier, from whom I am borrowing this citation,¹² alludes pertinently to the fact that there was “something of the same kind in the elephant of the menagerie at Versailles, described by Perrault.” As a general rule the sole of the foot in the elephant tends to be turned up behind so as to form a slight rim on the side opposite to that which bears the nails. This character may become abnormally prominent in individuals living in menageries. According to Perrault’s description and figure,¹³ it appears that such was the case with the one which he described, and it is interesting to see that “something of the same kind” may be shown by a mammoth.

I have observed at the periphery of the soles of the hind feet of the mammoth presented to the museum by Count Stenbok-Fermor not merely simple rims but horny excrescences forming as it were supernumerary nails and resembling nails so perfectly that it might be relatively difficult to distinguish one from the other. I have also been able to make on an Asiatic elephant that had lived in the menagerie of the Paris Museum an observation which corroborates that of Perrault, and which allows me to assert without hesitation that these anomalies of menagerie elephants are of the same character as those which were shown by the mammoths.¹⁴

tusks of the wearing down that I have spoken of above, produced by voluntary rubbing against trees.

In any event the tusks of the mammoths could not have been, I repeat, anything but accessories that were more incumbering than useful. If this is not an instance of real degeneration the result, nevertheless, must have been injurious rather than favorable to the preservation of the species.

¹² *Ossements fossiles*, ed. 4, vol. 2, p. 232. Paris, 1834.

¹³ *Description anatomique d'un éléphant mâle*, *Mémoires de l'Académie royale des Sciences*, vol. 3, pt. 3, 1734, pp. 91–156 (see pp. 103–104 and pl. 19).

¹⁴ Here again I think I must make a digression concerning the terms of comparison furnished by the recent elephants.

In these animals the number of toenails is subject to frequent individual variations. It is classic, but incorrect, to say that the African elephant has four nails on the front feet and three on the hind feet, while the Asiatic elephant has five of them in front and four behind. These numbers are not constant. Especially in the Asiatic elephant, better known than its African congener, there may be four nails on each foot, or five, or four in front and five behind, contrary to the generally recognized type. Aristotle, noticing the relation of these nails to the digits, suggested that they were not true nails; this view

The presence of the rims or horny excrescences which thus surrounded the soles of the hind feet of the latter proboscidiæ, especially when developed to the extreme degree shown by certain individuals, must have peculiarly interfered with walking, even on nearly bare soil, and must have made it practically impossible on ground covered with brushwood. There is a great difference between these conditions which may, I think, be called unhealthy, and the adaptive characters shown by certain ungulates which habitually live in marshy regions, *Limnotragus*, for instance. For the mammoths this was a cause of weakness which it seems to me necessary to point out.

In view of the group of conditions thus enumerated is it still possible to regard the mammoth as having undergone a process of adaptation conferring on it a special power of resistance to the hardships of a habitat under a glacial climate? I do not believe so.

If it had been able to flee before the invasion of the cold and to reach temperate or hot regions, perhaps the mammoth would have survived like the present-day elephants, of which it shows itself to be in general such a near relative. But it probably did not have the faculty of adaptation which we see existing in the elephants and of which we can analyze some important details. Not having been able, for reasons which I can not trace, to leave the regions which had become particularly inhospitable to it, the mammoth was perhaps subject to the effects of an alimentation made more and more difficult by the gradual depauperization of the vegetation. In any event, it was subjected in a specially inexorable manner to the attacks of the cold against which it was ill protected. In a general way this cold must have caused the species to degenerate; moreover the individual accidents which it occasioned could not help being frequent.

Attempts have been made to trace in detail the causes of death in some of the individuals found frozen. Traumatism occasioned by falls into crevasses or by land slides certainly brought many of these individuals to their death. The Beresowka mammoth presents a good example of this: multiple fractures with vascular ruptures and extensive hemorrhages, the whole seeming to indicate a

is particularly applicable to the supernumerary nails which the elephant sometimes shows as well as the mammoth. The description, already cited, by Perrault is very instructive in this respect. The Versailles elephant (from the Congo) showed such pseudo-ungual growths having a length up to 13 inches and "twisted in a very odd fashion." "It was necessary," Perrault adds, "to saw them off, because these excrescences were in the elephant's way when walking" (p. 104). In the case of this kind which I examined in an Asiatic elephant the nails, as in the mammoth, showed an irregular wall bearing transverse very irregular thickened rings whose presence and whose characters gave evidence of an altogether erratic growth. Strictly speaking the nails were not hypertrophied unless in length; the portion called keraphyll extended from base to tip. The whole structure bore the marks of an irregular development and not of a simple hypertrophy. Structures formed in this way are, I insist, wholly inadapative. Once more it is to be insisted, such anomalies, carried so far, are for the elephant the result of menagerie life, while for the Siberian mammoth they were natural, related apparently to special conditions of habitat to which the animal was unable to react by the acquisition of adaptive characters, anomalies which in the end brought on its disappearance.

violent blow like that produced by a fall from a high place, could be observed under conditions which appear to be beyond criticism.

Brandt thought he could prove from the condition, and notably from the color of the contents of the blood vessels in the head of a *Rhinoceros tichorhinus* found under conditions identical with those under which the remains of mammoths are found, that this animal died of asphyxiation. This specimen has been made to serve as an argument for death by asphyxiation from immersion in the case of the mammoths recently discovered and to serve as proof of diluvial cataclysms. Fatal accidents from immersion in water or from miring may have been frequent without, however, its being necessary to regard them as connected with cataclysms. Let it again be noticed, moreover, that here once more it is illusory appearances which have furnished material for explanations. Formerly capital importance was attributed to the color of the blood in diagnosing death by asphyxia; certain old masters of legal medicine were imbued with this idea, which Brandt applied to his rhinoceros. But it is now proved as concerns man that "if at the moment of death there may exist some difference in the color (of the blood), according to the particular kind of death, this difference vanishes in the time intervening between death and the autopsy."¹⁵ Neither have local congestions any diagnostic value. I will mention further that the condition of the blood, such as Gautrelet and I have described it in a mammoth, only allows very limited investigations. The carcasses of mammoths are far from being found in perfect preservation; generally nothing more than shreds are dug out, in which the skin, flesh, and cartilages are sometimes apparently in a fresh condition; as for the rest, it is destroyed or profoundly altered. Gléboff (1846) thought he had found blood corpuscles and nervous elements, but these corpuscles were only grains of dust, and these nerve fibers were only bits of mycelium of saprophytic fungi.

All the ordinary causes of death from cold must have acted on the mammoth. The snow, the icy rains, could have penetrated the curious fur with which the animal was covered; the fur must then have transformed itself into a veritable cloak of ice, not merely in a superficial manner, but down to direct contact with the epidermis. This was deprived for its part of the very efficacious protection which in other mammals is furnished by the continual discharge of sebum and sweat.

Finally it does not seem to me that the essential character of the mammoth's skin—that is, the absence of cutaneous glands—can be regarded as having been progressively developed in this species, whose first representatives would have been, on this hypothesis, better protected than the last. We see the same character existing in the

¹⁵ Thoinot, Précis de médecine légale, Paris, 1913, vol. 1, pp. 615-616.

recent elephants; it must be very ancient and has probably appeared coincidentally with the differentiating of the proboscidian type, as has probably been the case with certain other characters which are very special and even very aberrant. The strangest of these is, I think, the obliteration of the pleural cavities which the Asiatic and African elephants normally show from the time of birth (it appears rather late in the fetus) and which is peculiar to them.

To sum up: So long as the external environment was favorable enough to permit the mammoth not to suffer from the causes of inferiority with which it was afflicted the evolution of the species was able to go on not only without incumbrance but with enough vigor to have temporarily assured the dominance of these creatures, whose gigantic size reached perhaps that of the most formidable living elephants, which may measure nearly 4 meters at the withers.¹⁶ What a difference between such individuals and the one found by Count Stenbok-Fermor's prospectors. Were such representatives the degenerate descendants of the first? It is possible. It would even be tempting to say that it is probable. However, let us be prudent on this subject, and to fortify ourselves in this prudence let us try to calculate the conditions under which identical questions will present themselves to the paleontologists of the future.

¹⁶ Mr. Boule has called my attention to the fact that it is best to accept only with the greatest reserve some of the statements which attribute a gigantic size to the mammoth. The question is worth looking into, and in order to throw some light on it I think I should here offer some numerical data.

It was formerly agreed that the mammoth might exceed 5 meters at the withers and might bear tusks 7 meters long, each weighing about 200 kilograms; there was here apparently a certain amount of exaggeration and, in some instances at least, a confusion between *E. primigenius* and other extinct proboscidiens. In opposition to these exaggerations it has been asserted that the stature of the mammoth did not exceed that of the recent Asiatic elephant. (Woodward, *Outlines of Palaeontology*, Cambridge, 1898, p. 307: "The extinct species (mammoth) does not appear to have exceeded the modern Indian elephant in size.") The maximum height of this latter species, at the shoulder, is about 2.9 meters, a maximum rarely attained, however. According to their mounted skeletons the Adams mammoth, from the mouth of the Lena, measures a little more than 3 meters at the shoulder, and Count Stenbok-Fermor's specimen from the Liakhof Islands—that is, from a somewhat more northern deposit—measures only 2.5 meters.

But it can not be questioned that other mammoths (I am here considering only the Siberian mammoths which are found actually frozen) reached a greater size. Leaving aside all statements which I can not support by authentic measurements, I shall limit myself to pointing out some data furnished by the size of the tusks.

There is no constant relation between the size of a proboscidian and that of its tusks; very large individuals may have very small tusks. But the inverse is not true; an elephant of very small size could not bear the burden of very large tusks. I should hasten to add that even here no rule of proportion can be established, and the case of the mammoth is, I think, the proof of this. According to standards furnished by the recent elephants, the mammoth, I repeat, bore tusks which were entirely out of proportion with its stature. (See above, p. 333.) But admitting this, it appears to me impossible not to regard certain gigantic mammoth tusks as having belonged to animals whose size was greater than that of the Adams and Stenbok-Fermor specimens. Ward's Records mention a mammoth tusk 3.65 meters long and 0.48 meters in maximum circumference, and another 3.35 meters long, 0.53 meters in circumference, and weighing 79 kilograms. These measurements are already much above those furnished by Asiatic elephants, with a maximum length of 2.71 meters, a maximum circumference of 0.445 meters, and a maximum weight of 48 kilograms. But a mammoth tusk which may be seen in the galleries of

When these paleontologists exhume in certain districts of Africa—for example, in certain parts of the basin of the Sobat or in certain regions near Lake Rudolph—the remains of the elephants which are now living there, they will feel in the presence of these colossal remains of a mammal which will then be extinct, the stupefaction which the discovery of the *Diplodocus* caused their predecessors. And when they find in other regions relatively not far removed from the preceding—for instance, at certain points in Somaliland—remains of elephants which were not so tall, and whose general form was more compact, they will probably try to find what relations can exist between these types. Perhaps geology and paleontology will teach them that Africa was undergoing at our epoch a progressive desiccation, and that this process was nearly complete in Somaliland while the regions previously mentioned were still rather freely watered, even marshy in places; perhaps they will thus be led to believe that the differences in vegetation due to these causes had placed the Somaliland elephants at a disadvantage, and that, for instance, our *Loxodon africanus orleansi* would only be a degenerate representative of the group of the *L. a. knochenhaueri*, *peeli*, *cavendishi*, *oxyotis* . . . But we know that such is not the fact. The first of these elephants is a mountain animal, very strong, very active, made particularly combative by certain conditions of insecurity, but still finding in the region where it lives an ample food supply and altogether the opposite to a degenerate animal.

Let us therefore not be hasty in assuming such relationship between the largest Siberian mammoths and some few small individuals, even if these latter were found in the extreme north of this region. We must hope that new material will soon throw new light on this subject. Let us hope especially that such specimens will be collected with the most extreme care, and that all details as to their condition and deposition will be very exactly determined. Meanwhile it is permissible to regard the extinction of the mammoth as having probably come about progressively through degeneration, resulting from lack of adaptation to cold, a degeneration which was probably aggravated by some other causes of inferiority, and which was accelerated, perhaps, by a gradual diminution in the food supply.

comparative anatomy of the Paris Museum exceeds all these records; although sawed off at the base and broken at the tip it measures along the outer side of its curve 3.62 meters, and its total length must have been in the neighborhood of 3.90 meters; its maximum circumference reaches 0.60 meters. However out of proportion this tusk may have been to the size of the animal that it came from, the latter must have been, to be able to bear a pair of appendages of this magnitude, much larger than those whose height has just been mentioned. I may add that this last specimen came from the banks of the Kolima; unfortunately I can not give the locality more exactly, but in any event it is a little more to the south than the localities where the Adams and Stenhok-Fermor mammoths were found.

A PRELIMINARY STUDY OF THE RELATION BETWEEN GEOGRAPHICAL DISTRIBUTION AND MIGRATION WITH SPECIAL REFERENCE TO THE PALAEARCTIC REGION.¹

By COL. R. MEINERTZHAGEN, M. B. O. U.

In studying the migration of birds we can not confine ourselves to a narrow view of dates of arrival, weather influence on migration, routes of migration, etc., but are necessarily compelled to inquire into other ornithological problems which directly influence migration, such as the questions of molt, sustenance on migration, and others, among which the problem of geographical distribution is all important.

Until quite recently the study of migration was built on a sea of theories, sometimes based on no evidence and at other times based on insufficient data. Many authors had generalized on purely local facts and attempted to apply to all birds a principle which was only manifest in a single species at some isolated lighthouse or on some island observatory. The interpretation of facts was often attempted before those facts were themselves accurately known, and opinion was in many cases based not on knowledge, but on conjecture. The result is that many distinguished authors did, and do still, hold opposite views on similar migration problems.

By applying existing theories to migration in general, it was found that they were usually only applicable to a particular species at one particular spot, and it became apparent that until a fairly comprehensive grasp could be got of the migration of each species throughout its range we should not progress to any great degree.

The rules governing the migration of a species in Great Britain need not necessarily apply to that same species when passing from its summer quarters in other parts of the world to, say, India or Egypt. Each species contains many communities, and even very small local colonies, whose summer and winter homes and routes of migration are governed by laws which are almost individualistic. Not only each species and subspecies, but every small colony or family of birds presents on occasions a separate problem, the solution of which may differ in accordance with the many varied laws governing

¹ Reprinted by permission from *The Ibis* for July, 1919.

the migratory habit. In this connection it is interesting to quote Whitlock (Migration of Birds, final paragraph):

Every species, nay, every little clan of birds has its own migratory history, resembling as a whole the story of the common flight, but on the other hand differing in many points in its minor details.

Before, then, the migration of any species can be studied as a whole, a detailed knowledge of its geographical distribution will be necessary, and in grappling with this question we are at once confronted with the question of subspecies or geographical representatives.

A subspecies is an incipient species and is evolved ab initio from exactly the same causes as a species. The causes of variation in species or subspecies may be roughly summarized as follows: We may attribute variation in size to the quantity or quality of food, variation in structure to some essential habit developed in the daily search for food (it is hoped to show at some future date that length of wing is not dependent on length of migration, but on daily habit), special decorative development to courtships necessitating nuptial display, the thickness or extent of the feathered regions to climate, and variation in color to climate or local surroundings or food. A high temperature, a dry atmosphere, and a bright light seem to produce that bleached effect usual in desert forms. A temperate climate, moist air, and a dull sky tend to dark plumage. Alpine and Arctic forms display more white than is noticeable in the same bird from farther south or from lower altitudes; though we see in the case of *Corvus cornix capellanus* the brilliant glare of the Persian Gulf having the same effect on plumage as the glare from the Arctic snows has on many northern forms.

It is curious that it is the influence of the breeding quarters which causes differentiation, the winter quarters and regions traversed on migration having little effect on coloration or structure. Wide-ranging and common species show the most variation, so long as their breeding area is not restricted, as in some of the Polar breeding species. It therefore seems likely that it is the nursery which tends to differentiation. This is most remarkable in such birds as *Cuculus canorus* and *Micropus apus*, whose nursery life scarcely extends to a quarter of the whole year, and among which several well-marked geographical forms exist which in some cases share a common winter quarters.

But it seems by no means proved that the breeding quarters of a species is necessarily its real home, though it is undeniable that the present breeding quarters of a species produces the homing influence on spring migration. Seebohm (Geog. Dist. of the Charadriidæ) has already pointed out that it is possible that the present winter quar-

ters of migratory birds breeding in northern latitudes coincide with the old breeding quarters of the same bird's ancestors in the post-Pliocene glacial period. It seems probable that a species with a confined breeding area and an extensive range in winter had its original home in the confined breeding area to which it is most attached, for this area is much more exact and local in influencing the bird's life, and becomes the focus of its migrations. On the other hand, it may be that a species with a wide breeding range and a confined winter quarters was originally evolved in its present winter quarters, which retains the hereditary attraction due to the love of a bird for its old home. In this and in other ways geographical distribution, when closely studied, will be found to be most suggestive of a bird's past migratory history.

In this connection it is interesting to note that, though a particular form of bird chooses for its winter quarters an infinite variety of climate, in most cases the breeding quarters in the breeding season show no great variation of climate, though these may cover a vast latitudinal area.

The much-debated question of trinomials is outside the scope of this paper. The value, however, of subspecies to the student of migration is immense, and the more a species can be split into geographical forms the easier becomes its migration problem and the determination of its correct geographical distribution. Throughout the southern part of the Palaearctic region we frequently find more than one form of a single species wintering in the same area, and with the help of subspecific differences, however small or distasteful to the conservative binomial ornithologist, we can at once recognize the breeding area of the bird in question and its probable migration route, provided we have reliable information regarding its geographical distribution.

Geographical distribution includes, in the case of migratory birds, the breeding area, the winter quarters, and the routes of migration connecting these areas in spring and autumn. Very few species in the Palaearctic region can be classified as true residents throughout all seasons, though many might appear to fulfill the conditions of a resident species until their movements are closely studied. A disregard of the importance of a species' distribution at all seasons has largely discounted the value of many ornithological works and papers, for the mere mention of a species occurring at a certain locality, without date or further detail, does not really advance our knowledge of the geographical distribution of that species, but rather confuses it and encourages misleading deductions.

In writings on the birds collected in a certain area we frequently see a great amount of detailed description of the birds collected, their

wing measurements, etc., and, except for the number of specimens obtained and their sexes, no further detail. A rough guess can be made at the date of collection from the time of year during which the collection was made, but this even is often impossible. There is rarely any indication as to whether the species was common or whether the specimens collected were the only ones observed, whether the bird was resident, on passage, or in winter quarters. Again, how frequently the major value of a paper is lost by failure to grasp the importance of assigning subspecific value to those specimens which represent geographical races. The occurrence of the song thrush in Portugal is of little value without knowledge as to whether the bird is of the British or continental race; or, again, the passage of the redstart in Egypt or Palestine loses its importance without a determination of its subspecific rank, which alone helps us in studying the bird's distribution and migration.

It is perhaps ungenerous thus to criticize the great efforts made by field and museum naturalists, but the writer himself being an offender in this respect, reference is made to this most important point in the hopes of stimulating further effort to gain the maximum results from the slaughter of such beautiful creatures as birds, to enable us to interpret correctly the many and varied facts with which nature presents us and to solve the complex problems of distribution and migration. No killing of birds can be justified merely to compile a list of species obtained in a certain locality. Careful field notes by the collector and an accurate determination of subspecific rank (where this exists) by the man who works out the collection can alone justify its formation. A mere list of birds likely to be found in almost any part of the world could be compiled by any studious ornithologist in the library of the Zoological Society in Regents Park, without a visit to the locality in question and without taking the life of a single bird.

Neither are we dealing with a science which is stationary. Geographical distribution and migration have been in the past, are now, and always will be fluctuating, sometimes imperceptibly, sometimes by leaps and bounds. The same applies to the geographical races of a species. As distribution and migration alter, so do subspecies become evolved, usually very gradually, but sometimes within the lifetime of man. But the problems remain constant, and the laws which govern these problems change but little.

The extent of the geographical distribution or range of a species, on which largely hinges the differentiation in both species and subspecies, is due to—

1. Gradual expansion or contraction.
2. Periodic and regular migration.

3. Sporadic migration, invasion, or extensive wanderings.

4. Human agency, direct or indirect.

A few cases will be taken to illustrate these problems which so closely link distribution, migration, and differentiation among birds.

1. GRADUAL EXPANSION OR CONTRACTION.

Birds have been known to gradually extend their range into every point of the compass, and it will probably be found that normal expansion radiates from the bird's original home. It is interesting to note that the Charadriidae are believed by Seebohm to have originated in the north, and the swallows have been credited with an early home not far removed from the Tropics.

But it is more recent and current movement which now concerns us.

An example of gradual expansion to the south is well illustrated by the range of the crested lark (*Galerida cristata* and its subspecies), whose original home was probably central and western Asia. This species has now amplified its distribution from France to Korea; and south to Sierra Leone and Senegambia, on the west coast of Africa, and Abyssinia and Somaliland, on the east coast; and to Ceylon. It would appear from an examination of this distribution that expansion has followed coast lines, which, as pointed out by Hartert (Novit. Zool., xx, 1913, p. 76), is a tendency not only among migratory but among such sedentary species as the white owl, chough, circl bunting, and others. But here, in the case of *Galerida cristata*, we see expansion and differentiation progressing concurrently; and there can be little doubt that the crested lark, a hardy species capable of residence in the snows of central Europe and Asia or in the heat of the Red Sea littoral, will not check its expansion till the Cape Seas arrest its progress. Its advent on the west coast of Europe is probably of comparatively recent date, for it has never established itself in Great Britain, though there can be little doubt it would have done so during the last century if its efforts had not been checked by the greed for rare birds.

The shore lark (*Eremophila alpestris flava*), which in comparatively recent times has become a common breeding species in Arctic Norway, affords a good illustration of gradual expansion to the west. At the same time as expansion of breeding range, these birds opened out a new line of migration about 1847 (Gaetke) and became a common bird of passage at Heligoland in spring and autumn. This fact is of particular interest, as other northern species (*Phylloscopus borealis borealis*, *Anthus gustavi*, and *Emberiza pusilla*) have, in spite of westward extension of their breeding range, rigidly adhered to their ancient migration route and winter quarters in southeast Asia. Cooke (Migration of Birds, p. 6) further illustrates the

phenomenon of westward extension in the bobolink, which species rigidly adhered to its ancient migration route though adding 1,000 miles to its line of flight.

Gradual expansion to the north can be found in the case of the greater spotted woodpecker in Great Britain and in the case of *Passer moabiticus moabiticus*. This latter bird, formerly confined to the south end of the Dead Sea, is now commonly found in the Jordan Valley at the north end of the Dead Sea and will doubtless extend to Galilee.

Eastward expansion, though the example must be taken from outside the Palaearctic region, is well illustrated by the gray parrot in equatorial Africa. This bird, formerly unknown much east of Uganda, has rapidly extended its range across the Mau Plateau and Rift Valley, and will ere long find itself on Mount Kenya and thence to the east coast of Africa.

Gradual contraction of range from natural causes may be due to meteorological or climatic conditions. Gaetke (Birds of Heligoland) quotes the erosion of the Heligoland cliffs as partly destroying the breeding haunts of the guillemot and razorbill. A cyclone in Mauritius almost exterminated the local species of martin. The sudden rising of water on an artificial lake in Baluchistan completely destroyed many dozens of nests of a grebe, together with many hundreds of their eggs, and the whole colony of breeding birds moved that night and have not since returned to that lake as a breeding species.

Or contraction may be due to inability to establish a migratory habit, which we see after severe winters among some of our own resident forms; or to an insufficiently developed migratory habit, as with certain communities of redwings, fieldfares, and starlings, who perish in the south of England and Ireland in very severe weather rather than continue their passage to southwestern Europe, as do other communities of the same species who have developed an increased migratory line of flight.

Or contraction may be due to expansion in range of some other species which becomes an evicting factor. The jackdaw is believed to have been largely responsible for driving the chough from the cliffs of southern and western England. The house sparrow, in extending its range in Russian Turkestan, has supplanted the tree sparrow and has evicted the house and sand martin from many nesting haunts in England. The puffin has replaced the Manx shearwater in some of the islands of the inner Hebrides.

Food supply will also contract the range of a species, though this is usually only a temporary inconvenience.

Gradual contraction among nonmigratory species will eventually produce interrupted distributions, extermination, or isolation. Of

the first of these conditions *Sitta canadensis*, occurring in Corsica, China, and America; *Cyanopica cyanus*, in Spain and Eastern Asia; and *Pyrrhocorax pyrrhocorax*, with its reported isolated colony in Abyssinia, afford good examples.

Isolation will in its turn most assuredly produce differentiation. In these three above-quoted cases there can be little doubt that the isolated colonies emanated from the same parental stock and that they primarily emigrated from the same area. As in Mesopotamia, we find derelict remains of ancient civilization, such as the banks of some Babylonian canal, cropping up at sometimes great intervals, and only giving us a general clue to a once huge work, so we find among some species derelict groups or forms cropping up in widely separated parts of the world as landmarks of some bygone migration or continuous distribution.

Such gradual movements as are outlined above, when undertaken by what are commonly believed to be resident species, represent in fact incipient migration or movements from which a strong migratory habit has since developed in other species.

2. PERIODIC AND REGULAR MIGRATION.

We see periodic and regular migration effecting changes in breeding-area in certain species of Palaearctic birds. We find the bee eater (*Merops apiaster*) taking advantage of South African conditions and establishing breeding colonies there. (Stark and Sclater, Fauna of South Africa, Birds, iii, p. 59.) That this species breeds regularly in Algeria and Egypt is beyond question, and it seems possible that it also breeds in the northern Sahara. (Novit. Zool., xviii, 1911, p. 524, xx, 1913, p. 60.) It is not then surprising to find them nesting in South Africa, where conditions are more favorable than in north Africa. But it is not inferred that this bird breeds twice a year, once in its normal summer haunts and again in its winter haunts. It is more likely that the colonies which breed in South Africa are resident communities who have dropped the migratory habit as redundant to their life.

Again, we find the sandpiper (*Totanus hypoleucus*) nesting in tropical East Africa (Van Sommeren), and the writer observed the young of this species with their parents on the Kajiado River near Nairobi in 1915. The pratincole is reported to have bred in a colony near Durban in November, 1917 (Ibis, 1908, p. 385), Geoffroy's sand plover is suspected of breeding in Somaliland (Archer), and the swallow (*Hirundo r. rustica*) in Uganda and on Kilimanjaro.

It is held that these cases of expansion of the breeding range are directly attributable to migration, as they all occur among species in which the migratory instinct is strongly developed. Whether or no

these instances are cases of incipient isolation remains to be seen. If this is the case, we shall get differentiation, as in the case of *Corvus cornix*, the hooded crow, which has two communities, in Egypt and on the Persian Gulf, both of which have lost the migratory habit, and one of which has assumed considerable differentiation.

It has been stated (Eagle Clark, *Migration of Birds*, i, pp. 15-17) that southern tropical regions are not suited as a nursery for the hardy northern birds, and if breeding were attempted in such regions the species would become extinct.

Facts do not entirely support this view, though doubtless it is true as a broad principle. We have already referred to the hooded crow, an essentially hardy northern species and one of the few birds remaining in Arctic Norway in winter, as breeding under one form (*Corvus capellanus*) on the shores of the Persian Gulf, one of the hottest parts of the world and eclipsing the heat of any part of tropical Africa, while yet another undifferentiated form is resident in Egypt and northern Sinai. We find a swallow (*Hirundo savignii*) breeding in Egypt, various forms of the white owl and kestrel throughout the Tropics of Asia and Africa, and other birds such as *Saxicola torquata*, the stonechat, with geographical races equally at home from the Arctic regions to Cape Town.

All such distribution, as illustrated in this last paragraph, is due either to gradual emigration or to a regular migratory habit at some remote period, and has depended for its success on the initial capacity of a species to adapt itself to new surroundings, which was possibly a case of necessity in the earliest attempt.

In this connection it would be interesting to ascertain whether the same species, when nesting in tropical countries, lays fewer eggs in the clutch and rears more broods in the season than the same bird in more northern climes. The blackbird is said (Chapman, *Wild Spain*) to lay but three eggs in Spain, to raise three broods in Tangier (Favier), whilst in the Canaries the local blackbird (*Turdus m. cabreræ*) lays very few eggs in the clutch. (Ibis, 1912, p. 597.) The wren (*Troglodytes*), a prolific breeder in northern climes, appears to lay but four eggs in the normal clutch in Sicily. (Ibis, 1912, p. 171.) Is such the case among other species which have tropical representatives? The point is submitted to the many distinguished oölogists whose vast collections might help to solve the problem. Is the normal clutch regulated by the capacity of the parents to feed the young (or water the young, in the case of sand grouse), or by the limits of brooding surface on the parent's abdomen, or by the normal mortality in the species, or by what? Even such questions have influence on migration and distribution, for it is by no means certain whether birds go to the Arctic regions for reproduction, on account of their ancient love for home, or to enable them to get suffi-

ciently long days to collect a satisfactory supply of food for their offspring, or whether merely because the Arctic regions offer a more prolific food supply than more southern regions. If either of the two latter causes are correct, we should expect to find the Charadriidae and Anatidae which breed in the Tropics to lay fewer eggs in the clutch than those which breed in northern Europe. We know that a plethora of food reflects itself on reproduction (c. f. snowy owls and rough-legged buzzards in lemming years in Scandinavia, and the increase of hyenas after wholesale deaths among natives in East Africa).

3. SPORADIC MIGRATION, INVASION, OR EXTENSIVE WANDERINGS.

The well-known invasions of *Syrnhaptes* need no comment. That they would lead to eventual permanent colonization is almost certain, but so far the species has never had a fair chance. There is no reason, however, why the wide distributions of *Pterocles arenarius* or *P. senegallus* should not have been initiated by colonization after sudden invasion, for the sand grouse as a group are essentially wanderers in search of suitable and rather specialized food, seeming to pride themselves on erratic movement and ignoring any seasonal lines of flight, which, generally speaking, constitutes migration; though in some spots they are particularly regular on migration, as is the case with *P. arenarius* of northern India.

The rose-colored starling, aptly described as a veritable gipsy among birds, gives us a further illustration of colonization (in Italy and elsewhere) after invasion; and the various subspecific colonies of the crossbill (*Loxia curvirostra*) in the Mediterranean region might equally be due to colonization after eruption at some remote date, as opposed to either gradual expansion or regular migration, though the accuracy of such a theory to account for their present distribution is by no means certain.

4. HUMAN AGENCY, DIRECT OR INDIRECT.

The introduction of such species as the pheasant, goldfinch, and starling to various parts of the world will suffice to illustrate expansion of range due to direct human agency. In the case of the goldfinch, we find in the Bermudas that the bird has already established for itself a differentiation entitling it to subspecific rank. In the case of the introduction of the starling to Cape Town, it is interesting to note that the species has abandoned the migratory habit and has become a pure resident, not even congregating into flocks in winter.

Contraction of distribution under this heading is the sad story of extermination, being generally confined to species having a very

local breeding area, such as the passenger pigeon, Esquimaux curlew, and Labrador duck, or to species, which, having a large range, are unable to resist slaughter at all seasons. Systematic egg stealing under the cloak of science, but which in reality is the travesty of science, is also responsible for such contraction of range, as in the case of so many birds which have within the last century ceased to be included among British breeding species.

Indirect human agency has increased the breeding range of certain species, though only in a minor degree. The reafforestation of land and artificial sheets of water have, no doubt, helped in this manner, though in most cases it has been a case of reestablishment. The carrying of migratory birds on ships comes under this heading.

In like manner has interference with terrain, such as the draining of the fens, contracted the breeding range of birds. The introduction of a destructive element has had similar effect, as in the case of the arrival of the pig in Mauritius, which completed the sad fate of the dodo, or the great mortality among sea birds from the torpedoing of a tank steamer and the resultant film of oil spread over vast areas of sea.

CONCLUSION.

From these examples it will readily be seen how closely related are migration, distribution, and differentiation among birds. Without the framework of distribution the study of migration can only lead to theory. Each separate species or subspecies must be studied, if possible, throughout its range, and then we shall arrive at facts from which the whole narrative of migration can be read. No two species which have a similar geographical distribution are known to have similar migratory habits. We even get, among birds of the same species, vast differences in migratory habit, hence the great importance of detailed study.

The task is gigantic, and though no one human life can hope to complete the work, a combined effort by all field naturalists and collectors, with the very great assistance supplied by the various organizations in Britain, America, and on the Continent for the study of local movement, not to mention that most valuable of all schemes, the "ringing" of birds, will go far to building up an edifice grounded on solid facts, whose completion we must leave to future generations of enthusiasts.

Finally, it must be clear to any reader of this rather fragmentary paper that no exhaustive or complete study of the subject has been attempted. Many points connected with the relation between distribution and migration have been merely suggested, in the hope that such preliminary mention will stimulate ideas on this, the most attractive phase of an absorbing science.

THE NECESSITY OF STATE ACTION FOR THE PROTECTION OF WILD BIRDS.¹

By WALTER E. COLLINGE, D. SC., F. L. S., M. B. O. U.,

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It is now generally agreed that birds as a class are highly beneficial and function as an important natural force in the control of the many insects that attack agricultural crops, fruit orchards, and forests. Realizing this, many countries have enacted laws for their protection and preservation, whilst some maintain departments wherein their feeding habits, migrations, increase and decrease, and general movements are studied, with great benefit to their respective nations.

The question is frequently asked, "Why should the State interfere with wild life; why should not birds and all other wild animals be left alone?"

In order to give an adequate reply to this question it is necessary to consider at some length the activities of wild animals and their relationship to mankind.

The nation or the individual who possesses objects of great value seeks by all legitimate means in their power to preserve such from wanton destruction or harm in any sense. Such action is highly commendable, for surely it is only right that anything that is conducive to the welfare of mankind and that we of the present generation have the privilege of enjoying should, if possible, be handed down for the benefit and enjoyment of generations to come. It is the duty of the State, therefore, to guard and conserve most jealously every object that tends to the uplifting and advancement of its people, irrespective of whether such objects possess any direct utilitarian value or not.

In the case of wild birds we have both an æsthetic and a utilitarian value attached to them. On the former we do not propose to dwell at any great length, for the love of wild birds is interwoven with our national life. In painting, statuary, poetry, and prose this is at once evident. We have associated with bird life purity, valor, fidelity, the love of freedom, and the exalting love of maternity. We have used the bird as the emblem of peace and contentment and to express the

¹ Reprinted by permission from the *Avicultural Magazine*, Vol. X, 3d ser., No. 7, May, 1919.

idea of grace and symmetry of form and of perfect adaptation to the environment. The song of birds—the “thousand blended notes,” as Wordsworth described it—has inspired the poets of all ages and countries, those of our own country being not the least. Some of the stateliest lines in English poetry refer to birds, as readers of Shakespeare, Shelley, Scott, Burns, Gray, Longfellow, and Tennyson will recall. The study of bird life has ever exercised an ennobling influence, in consequence of which in certain countries efforts have been made to make it a compulsory provision of the education code to arrange for the study of birds in the public schools, and in a modified form to the original proposition one of the States of North America has enacted a law requiring every teacher in the public schools “to give oral instruction at least once a month * * * relative to the preservation of song birds, fish, and game.” Legislation of this kind undoubtedly marks the commencement of a phase in the public mind that is likely to assume greater importance in the near future. As a recent writer states:

The systematic study of birds develops both the observational faculties and the analytical qualities of the mind. The study of the living bird *afeld* is rejuvenating to both mind and body. The outdoor use of eye, ear, and limb necessitated by field work tends to fit both the body and mind of the student for the practical work of life, for it develops both members and faculties. It brings one into contact with nature—out into the sunlight, where balmy airs stir the whispering pines or fresh breezes ripple the blue water.

Very similar ideas are expressed by Forbush, who writes:

There is no purer joy in life than that which may come to all who, rising in the dusk of early morning, welcome the approach of day with all its bird voices. The nature lover who listens to the song of the wood thrush at dawn—an anthem of calm, serene, spiritual joy sounding through the dim woods—hears it with feelings akin to those of the devotee whose being is thrilled by the grand and sacred music of the sanctuary. And he who, in the still forest at evening, harkens to the exquisite notes of the hermit—that voice of nature, expressing in sweet cadences her pathos and her ineffable mystery—experiences amid the falling shades of night emotions which must humble, chasten, and purify even the most upright and virtuous of men.

On the utility of birds we might dwell at great length and then be far from exhausting the subject. Few of us have formed any conception of the influence they exercise upon our food supply and many products of industry. Here we must strictly confine our remarks to their value as the guardians of our crops, our orchards, and our forests. How little do we realize what a potent factor for good wild birds are in this connection, what the sum total of their ceaseless activities means, and how intimately associated it is with the security of our food supply. Were it not for the benefits conferred by wild birds it would be impossible to successfully cultivate the majority of our crops. This statement may seem an extravagant one, but an

examination of a few instances will at once serve to show how true it is.

We are all familiar with the greenflies on the rose and have some confused idea of their enormous fecundity. We probably call to mind Prof. Huxley's computation of their amazing rate of increase, but few of us have ever seriously considered the potential danger of greenflies with reference to our food supply.

The late Prof. Riley, when studying the hop aphid, observed 13 generations of this species in a year. Assuming the average number of young produced by each female to be 100 and that every individual attained maturity and produced its full complement of young, "the number of the twelfth brood alone (not counting those of all the preceding broods of the same year) would be 10,000,000,000,000,000,000,000 (10 sextillions) of individuals." Such figures fail to convey any idea of the numbers, but dealing with these Prof. Forbush has pointed out that if these individuals were marshaled in line with 10 to a linear inch and touching one another, "the procession would extend to the sun (a space which light traverses in eight minutes) and beyond it to the nearest fixed star (traversed by light only in six years), and still onward in space beyond the most distant star that the strongest telescope may bring to view, to a point so inconceivably remote that light could only reach us from it in twenty-five hundred years."

But there is scarcely a cultivated plant that is not attacked by one or more species of greenfly, or aphid, as the naturalist terms them. Of the trillion of billions that infest the apple, pear, plum, and cherry trees, and the hops, wheat, beans, turnips, cabbage, etc., what becomes of them? They are eaten by the birds. Aphids in large quantities have been found in the stomachs of the whitethroat, the warblers, the tits, the wren, the goldfinch, the chaffinch, the skylark, and numerous other birds; and the same remarks hold good with reference to the insidious scale insects.

Most insects do the greatest amount of damage during their larval or caterpillar stage; they feed voraciously, their daily consumption of food often exceeding many times the weight of their bodies. Selecting a familiar example, the yellow-and-chocolate marked caterpillar of the currant or magpie moth, it requires about 170 of these to weigh an ounce; in their earlier stages, say, about 200. We have seen currant plantations infested with these and by counting the number on one bush have estimated nearly 1,000,000 to the plantation, or a total of $2\frac{1}{2}$ hundredweight. Had these been left undisturbed they would quickly have consumed the whole of the currant leaves and ruined the crop; but, thanks to the birds, they were deduced to insignificant dimensions long ere they had an opportunity of devastating the bushes. And so it is with numerous other crops.

We might continue to cite insect after insect and the birds that feed upon them, but one further case will suffice.

Trouvelot, who introduced the gipsy moth into the United States of America, specially studied the American silkworm, and respecting its food and rate of growth he made numerous experiments. The rate of growth and the amount of food consumed are astonishing. Upon hatching from the egg, the caterpillar weighs one-twentieth of a grain; when 10 days old its weight has increased to half a grain, or ten times the original weight; when 20 days old it weighs 3 grains, or sixty times its original weight; when 30 days old its weight has increased to 31 grains, or six hundred and twenty times the original weight; when 40 days old it weighs 90 grains, or eighteen hundred times its original weight; and when 56 days old its weight has risen to 207 grains, or four thousand one hundred and forty times the original weight.

When 30 days old this caterpillar will have consumed about 90 grains of food, but by the time it is fully grown, namely, 56 days, it will have consumed not less than three-quarters of a pound of oak leaves. Thus the food taken by a single caterpillar in 56 days equals in weight eighty-six thousand times the original weight of the animal. Well might Longfellow say of the birds:

They are the winged wardens of your farms,
Who from the cornfields drive the insidious foe,
And from your harvests keep a hundred harms.

In the interests of agriculture, fruit growing, and forestry surely the conservation of this wild life is worthy of State attention. We do not simply mean the passing of an act of parliament for the protection of certain species, but a daily study of their habits and activities and all their intricate relations to mankind.

"But what about birds that are injurious?" If those that are beneficial should be protected, surely those that are injurious should be destroyed. Our knowledge as yet of the feeding habits of wild birds is so fragmentary that it would be dangerous to make the unqualified statement that any species of wild bird is wholly injurious. Some are partly so, due in all probability to the fact that they are too numerous, as, for example, the house sparrow, the wood pigeon, the starling, etc., but there is reason to believe that if these species were much less numerous than at present the good they would do would more than compensate for any harm they might inflict. It is therefore incumbent upon the State to walk very warily when it proceeds to withhold protection or to frame repressive measures for the destruction of any species. In a like manner the granting of protection to a bird at present generally regarded as beneficial may lead to an undue increase in its numbers, and within a very short time it will

prove equally injurious. The problem is a most difficult one. Those who demand all-round uniform protection are equally as wrong as those who favor all-round destruction, and the State that listens to either side or allows such extravagant views to weigh in their deliberations is amassing troubles for the immediate future.

Only after a long and careful study can we arrive at a satisfactory conclusion. Experience shows that it is possible to learn with considerable precision the percentage of the different kinds of food. Let us take the case of the skylark. This bird requires about 6 pounds of food per year, "so that 10,000 birds would require about 27 tons of food in a year." As we now know the percentages of food eaten by this species we can analyze this figure. Of the total food consumed in a year 35.5 per cent consists of injurious insects, 3.5 per cent of neutral insects, 2.5 per cent of beneficial insects, 9.5 per cent of grain, 1 per cent of leaves, 2 per cent of earthworms, 1 per cent of slugs, 1.5 per cent of miscellaneous animal matter, and 43 per cent of the seeds of weeds. In other words 36.5 per cent of the food eaten is of benefit to the farmer, 50.5 per cent is of a neutral nature, and only 13 per cent injurious. Thus we have a debit and credit account: On the former side we place the loss of $2\frac{1}{2}$ tons of cereals, and on the latter something like 30,000,000 injurious insects and 30,000 slugs. Such a plague of insects left to themselves would have destroyed many more tons of cereals, root crops, etc. Thus the farmer is undoubtedly the gainer by an enormous tonnage of produce.

The indiscriminate destruction of wild birds has led to serious insect plagues in many countries, so that any repressive measures must only be the outcome of very careful consideration founded upon long and accurate investigations such as the above.

To provide against extermination, State reservations, as places of refuge, are necessary. Other countries have found such to be profitable investments apart from protecting certain species of birds.

The education of all who are connected with the land is another most important avenue for State activities if we are going to secure to generations yet unborn their birthright.

The subject of bird protection is an exceedingly wide one and worthy of the attention of every enlightened community. "The food relations of birds are so complicated and have such a far-reaching effect upon other forms of life that the mind of man may never be able fully to trace and grasp them," says Professor Forbush; but this must not be advanced as a reason why we should not steadily pursue our investigations of the subject, knowing how directly it affects mankind. If we do not we are jeopardizing our food supply, impoverishing the land, and lagging behind in the progress of knowledge, and for such apathy and omissions nature will surely sooner or later demand just retribution.

GLIMPSES OF DESERT BIRD LIFE IN THE GREAT BASIN.

By HARRY C. OBERHOLSER.

Stretching far away to the westward beyond the slopes of the Rocky Mountains lies the country of the Great Basin, the great desert region of the United States. From Utah and Arizona it reaches north to Oregon, and west to the lofty barrier formed by the Cascade Range, the Sierra Nevada and the San Bernardino and San Jacinto Mountains. This whole vast area is an almost continuous desert, spreading indeed its powerful influence to the contiguous slopes of the mountains that guard its confines. Yet it is not all alike, for many of its parts differ widely in climate, physiography, vegetation, and animal life. Mountain ranges of varying height and extent, sometimes close together, sometimes with broad valleys interposed, traverse the entire region, most numerous in Nevada where they are chiefly parallel, least so in parts of southeastern Oregon, extreme southeastern California, and southwestern Arizona. The loftiest of these are in central Nevada and in the Death Valley country of eastern California. The valleys and plains, often of great extent, are stretches of sand, gravel, or clay, with now and then the bed of an ephemeral lake conspicuously shown by its dazzling efflorescence of alkali.

Rivers are few, the two most important being the Colorado, which, except for a small portion of its course, is hardly within the region; and the Humboldt, which, after following a tortuous course across Nevada, discharges its waters into the outletless Humboldt Lake, thus offering itself as a great but ineffectual sacrifice to the all-devouring aridity of the desert. There are some smaller streams, but most of them, aside from such as issue from the high mountains, are only dry washes except during seasons of rain. Springs, some of considerable size, occur in the hills and even out on the open desert; while hot springs are to be found in a number of the valleys. Lakes, many of which, like so many of the streams, have but a transitory existence, yield some relief from the monotony of the broad expanses of parched land. Those that are permanent, with few exceptions, are in the northern part of the Great Basin, in Utah, Nevada, California, and Oregon. They are all shallow,

more or less salt or alkaline, have no outlets, and derive their support chiefly from springs or short mountain streams.

Heat and lack of moisture, which are the dominant features of the climate, increase markedly toward the south, and reach their extreme in parts of western Arizona and southeastern California, where a summer temperature of 100° to 120° in the shade is of almost daily occurrence, where the average aridity of the atmosphere is more than three times as great as in the eastern United States, and the annual rainfall, confined chiefly to the winter months, is only 3 to 9 inches.

Little of all this dreary and forbidding region lacks vegetation entirely, for only the mirage-haunted alkali plains and the barest rocky slopes of the seared desert ranges are shunned by the hardy desert shrubs. The bottoms of the valleys, the sloping or nearly level mesas, the sides of the hills and mountains are all clothed with a growth, sometimes scanty, sometimes wonderfully varied, of mesquite, sagebrush, greasewood, cactuses, yuccas, or other similarly characteristic forms. The only trees worthy the name, except on the mountains, which rise partly beyond the arid influence of the valleys and support in places forests of pines, are the cottonwoods, and these are found only at springs or along streams.

An environment apparently more uninviting to every form of animal life it would be hard to find; for the bare rocks, the reaches of sand, the pebble-strewn mesas, and the clay flats incrustated with salt and alkali offer seemingly no protection or concealment; while the fiery heat, the desiccating air, and above all the lack of water appear hostile alike to all kinds of living creatures. Yet life there is, and relatively much; lizards of brilliant hues scamper about over the sand or lie on the rocks to bask in the sun; coyotes roam the plains by day and bark from the hills at night; rock squirrels and wood rats inhabit the cliffs; the little pocket mice and the singular kangaroo rats live in holes on the gravelly slopes or among the sand dunes; and many birds of many kinds are conspicuous almost everywhere, as well in the summer as when during the seasons of migration their numbers in species and individuals are greatly augmented. Only the bare and barren expanses of salt and alkali in the valleys are uninhabited, and even here at times some bird of strong flight may be seen soaring on lofty pinion above the inhospitable region.

The lakes of the region form the great attraction for most of the water birds and those that are usually termed waders, and furnish, too, along their sometimes marshy shores, a home for various other species.

The American avocet, in its becoming attire of black, white, and cinnamon, is a conspicuous and characteristic figure about these

lakes, as in search of its food and insects and crustaceans it often, with wings half raised, daintily wades in the shallow water along the shores; or, having passed beyond its depth, rides out buoyantly upon the waves. Startled from its humble nest in the grass or rushes, the avocet employs all the arts and wiles known to the anxious parent bird in the endeavor to entice the intruder to a safe distance; and, even after the young have joined their elders on the beach, any threatened danger will bring the old birds about with loud cries and demeanor almost as anxious as when the nesting haunts are invaded. The avocet is always a noisy bird, and, by its loud, reiterated notes, has earned the significant sobriquet of "lawyer."

The black-necked stilt, trim and neat in its dress of black and white, and of even more distinguished appearance, is found almost always intimately associated with the avocet. In habits it is quite similar to its companion, though less demonstrative, and in the shallow water it moves with slow, dignified, almost ludicrously cautious steps, pausing every now and then, with bill half immersed, as if meditating or listening.

Many kinds of ducks—the mallard, gadwall, redhead, ruddy, and cinnamon teal—enliven the marshes as they pass to and fro in their businesslike way overhead or paddle about among the tules or out in the open water, sometimes alone in search of food, sometimes followed by their downy ducklings. The cinnamon teal is probably the most generally distributed of all the ducks that inhabit the Great Basin, for it is often to be seen at the springs, waterholes, and even wooden tanks in the midst of the desert, where scarcely do land birds find a congenial abode.

In many of the more extensive marshes may be seen the beautiful Forster tern, a bird which, though of wide North American distribution, is preeminently a denizen of the interior, and contentedly takes up its abode about many of the lakes of the Great Basin, undeterred by the heat and the drought of the desert, so foreign to its northern or eastern home. Graceful of flight as elegant of form, it is in its movements in the air a source of constant and fascinating delight to the observer. Starting from the stake, stump, or dead tree that may chance to be its resting place, it sweeps on easy wing low over the marsh, giving forth at intervals its harsh, cackling cry, or with bill pointed downward beats back and forth over the lake and the ponds looking for fish. But soon the eager eye has discerned its prey; the flight is arrested; with spreading tail and quivering wings the bird for a few seconds hovers in air; there is a quick plunge, a splash, and straightway the long, thin white wings rise with their burden, and the bird bears its booty away to young or mate. But "there's many a slip 'twixt the cup

and the lip," as well in the life of a tern as of men, and many a poise, many a descent, even many a plunge, brings no other reward than the lesson of patience and perseverance. Among the tules and other rushes that frequently border the desert lakes the Forster tern may be found breeding, often in close-crowded colonies and on friendly and intimate terms with grebes, gulls, or other marsh-loving species. The nest is built up from the ground, often with some care, of reeds and flags and other water plants, with a lining of similar material. The approach of any intruder is well-nigh sure to arouse a clamorous outcry from the rising birds, which dash threateningly at him from above, but when near at hand swerve to one side and pass swiftly by and up again to repeat the performance.

The well-known coot, in its somber dress of gray, with mask of startling white, frequents these ponds and lakes wherever there is promise of requisite seclusion. It moves unobtrusively in and out among the reeds that skirt the margins of the pools; and if at times it ventures more into the open, it is ever ready at the slightest alarm to seek the cover again. It may perchance be seen cautiously slipping away from its nest, on which it can scarcely ever be surprised; or it may be found swimming about surrounded by its gaudily bedecked but sturdy and precocious infants.

Tule Lake, in northeastern California, close to the western edge of the Great Basin, is a good example of the shallow, though somewhat extensive, desert lakes. It is so named from the common dark-green, round-stemmed tule, or rush, which grows luxuriantly in the water about its margin, particularly at the northern end. This growth of tules reaches out in places fully a quarter of a mile from the shore, now intermittently, now in wide stretches unbroken save by small spaces of open water, and forms extensive marshes that attract myriads of birds.

Among the waterfowl drawn to these marshes the western grebe is notable for size, dignity of appearance, and grace of carriage, as it lightly rides the water with head well poised and neck erect, and were it not commonly so retiring in disposition would much more frequently claim attention. Although it is able to fly well, its home is the water, and there in habit and action it is strikingly loonlike. It swims excellently even entirely submerged, or with but the head and the long bill protruding above the water, presenting then a strikingly serpentine appearance. Sometimes, when at rest on the water and seeking escape from observation, it may be seen to settle slowly lower and lower, as though drawn downward by an unseen force, till body, neck, and finally head sink out of sight, leaving not the suggestion of a ripple to disturb the mirrored surface of the water. Out in the lake, among the tules, it heaps up a rough-looking

yet sufficiently substantial nest of the dead and floating vegetation, molds a depression in the top for the two or three eggs, and moors the whole securely to the upright stems of the growing plants or leaves it to drift at the impulse of wind and waves.

A smaller, less sedate, more gayly attired species, the abundant American eared grebe lives in these great tule marshes in neighborly fashion with the western grebe, and builds a floating nest of typical grebe architecture, which is a familiar feature of the place. While the eggs are the object of her solicitude, the mother bird is always on the watch, and at the approach of any intruder hastily covers her treasures with the loose decaying vegetation of the nest and slips away; but later on, when the appearance of the little family has added to her maternal cares, she leads forth her vagrant brood to share with them the perils and the possibilities of the little world in which they move.

Multitudes of ungainly, dark-bodied cormorants roam this lake. They are awkward enough on land, but perfectly at home on the water, and able to swim long distances below the surface. Their nests are coarse structures of sticks and tule stems, which occupy either convenient niches in the rocks or the branches of low trees, and are to be found near those of pelicans, gulls, and herons along the eastern side of the lake on rocky islets covered with a growth of small willows.

Quite in contrast to the clumsy cormorant is the airy-winged black tern, whose name "water swallow" seems aptly chosen, for in its wonderful evolution as it courses the air after insects it recalls to mind most of all its smaller namesake of the land. Somewhat exclusive, too, is the black tern, and in its selection of a nesting place it withdraws to a separate part of the marsh.

South of Smoke Creek Desert in extreme western Nevada, wellnigh completely surrounded by low mountains and fed by the clear, cool stream of the Truckee, is Pyramid Lake. It is one of the largest and deepest of the Great Basin lakes; and in places the shores are precipitous, ascending sheer from the water, though seldom to great height, while here and there they are adorned with curious masses of calcareous tufa, fashioned into great domes or other strange forms. Two high, steep, rocky islands are conspicuous, and from the triangular, pyramidal shape of the smaller the lake takes its name.

To this body of water resort regularly and in numbers many species of shore birds and waterfowl, as well as land birds that have a fondness for bold cliffs near the water. A colony of California gulls occupies part of the larger island; the clumsy white pelicans also live there, and, whether foraging daily along the shores and the marshes at the head of the lake or straggling back to pitch their nightly camp,

they are picturesque and striking features of this wild scene; an occasional lonely great blue heron is to be seen, perchance passing to his immense nest on the rocks; the savage duck hawk makes frequent raids from his eyrie high up on an inaccessible crag; and multitudes of violet-green swallows skim the water's surface or, hovering about the honeycombed cliffs, pass in and out to their nests like a swarm of bees.

Southeastward beyond the low mountains that encompass Pyramid and Winnemucca Lakes there is a broad desert, the bed of an ancient lake, most of it level and marked by numerous alkali flats, hot, arid, and practically treeless save for the oases made by irrigation. Here are the "sinks" of the Carson and Humboldt Rivers, whose wide marshes, grown up to tules, flags, and rank grass, are alike in autumn, spring, and summer attractive to multitudes of birds. Strange-appearing white-faced glossy ibises, that move from place to place in flocks of often regular outline, much after the fashion of geese, line up along the shore or the edge of the marsh in their search for breakfast or dinner; night herons patrol the lagoons and the bayous by day and retire to the tops of the bushes or low trees at night; many kinds of ducks gabble over their possessions among the reeds; various wading birds pursue their wonted peaceful vocation on the flats; red-winged blackbirds chatter among the tules, or fly here and there in quest of food or nest material; and coots swim unconcernedly to and fro, unconsciously conspicuous in their gray plumage. A quiet contented community is here in this marsh in the desert, whose inhabitants live together in perfect harmony, and with rarely a disturbance from without. But sometimes that fierce marauder of the plains, the prairie falcon, appears on one of his forays. Then what a change! The varied voices are suddenly hushed; the blackbirds drop hurriedly into the rushes; the herons disappear; the ibises mount into the sky or cringe statue-like in their places; the shore birds scatter to the shelter that before they disdained; the ducks and coots scurry for their hiding places; and soon the place that just now was instinct with life and vocal with happiness is to every intent deserted by all except him that is the cause of the panic. Yet this dreaded intruder has learned by repeated experience not to advertise his coming, and possibly even now, as the signal of distress is being passed along, he has secured and is bearing away his victim.

From these marshes on every side the level desert reaches far away to the hills, in places bare, but mostly covered with a sparse growth of low, thorny shrubs, tufts of salt grass, gray-green annuals, and bright green greasewood, the last the only relieving feature of the landscape. Along the bases of the hills are areas where the bushes, spreading often into miniature thickets, catch and hold the

drifting sand until it rises into dunes and even at length completely covers the vegetation within. Among these sandy heaps the curious long-tailed kangaroo rats hold nightly revels, watched, or perhaps joined, by the humbler pocket mice. By day, after his springtime return, the shy little black-throated sparrow, nothing daunted by his cheerless environment, flits about in the bushes or on the ground, chirping contentedly the while. Then, after he has found his mate, and the cosy little nest is growing in the midst of yonder shrub, he gives expression to his happiness in a song of quaint, sweet, tinkling notes that are strangely attractive and far-carrying in the still air of these desolate surroundings. Into these sandy wastes comes also the horned lark, here as everywhere throughout the Great Basin a frequent and characteristic figure. Singly, in pairs, or in small companies, it seeks the more open places among the dunes and the brush, and roams the stony or bare sun-baked plains, venturing at times even out upon the wide level wastes of snowy-white alkali that covers in places the hard, heat-seamed clay soil, where scarcely another living thing appears, and nothing meets the eye but the blazing sky, the hazy, quivering atmosphere, and the barren landscape. Into such a furnace even the hardy desert inhabitants might well enter with timidity; but heat and aridity alike seem little to appall this pretty lark, for as it runs to and fro on the ground, or circles in towering flight like its cousin, the skylark, its cheerful twittering song appears to be just as happily an expression of its contentment here as in the beautiful, green, flower-strewn meadows of the far-away eastern country. From what few enemies it may have it is well protected by the colors of its plumage, whose browns and grays blend so perfectly and so marvelously with the surroundings, wherever in the desert the bird may chance to be, that to disappear from sight it has only to remain at rest.

The low rocky hills, with their scant vegetation of small shrubs, which rise beyond the sand dunes, lack but little of being as uninviting as the plains, yet the sprightly rock wren claims them as his own particular abode. Among the rocks, bowlders, and little ledges he may be found busy and active, and, though alert, not over-shy or suspicious. If started up from work or rest his quick, jerky flight to the nearest point of observation preludes a sharp, harsh note of interrogation and alarm, almost startling in its suddenness and volume, which degenerates into a prolonged sputtering scold, as the bird works himself into a ridiculous frenzy of voice and of action over what he doubtless regards as a wholly unwarranted and quite reprehensible intrusion. But his is an acquaintance that may well be cultivated, for once we are in his confidence he is found to be more than ordinarily interesting; he will sing for us, and this

performance is by no means monotonous or unattractive; or, confiding in our friendship, he may even lead us to the spot where, protected under an overhanging ledge or hidden away in a crevice of the rocks, is his little home. His lot, with several voracious mouths to feed in this all too barren land, might readily seem to be a hard one, but this is only apparent, for the desert yields to the patient toil of this little worker far more than falls under the gaze of the passing traveler.

A region of dry hills and vales, with occasional mountain ranges, succeeds the Carson Desert on the east, extending, with scarce an interruption more important than broad valleys, all the way to Utah and the Great Salt Lake. Typical desert vegetation covers this whole area: greasewood and other thorny shrubs in the lower valleys and on the hot slopes; sagebrush on the higher ground; and on many of the hills scattered junipers, which with their deep color give a little more variety to a needy landscape.

Characteristic forms of bird life, too, are here to be found. Haunting the cliffs, the canyons, and the rocky slopes, wherever its fancy dictates, the Say phoebe becomes almost an essential part of the scene, and many a time, though out of sight, announces its presence far up the hillside by a tremulous, mournful call. Perched often on some commanding outpost of the cliff, or on even so humble a place as a fence-post by the roadside, it makes frequent sallies into the air in pursuit of its prey, or at times, as it seems, simply in sport. It nests usually in some niche along the cliff, on a little shelf in some cave, in an old well, or about the timbers of an abandoned cabin, much after the manner of the familiar eastern phoebe.

Few birds are more characteristic of the chaparral throughout this region, and in other parts of the Great Basin as well, even toward the south, than the white-rumped shrike. Sinking from the summit of the bush on which it may happen to rest, it passes in rapid, undulating, well-sustained flight through or barely above the brush, its gray and white particolored plumage curiously suggestive of the mockingbird. Quite as individual a trait as its flight is its almost motionless pose on the top of a bush or post, where it waits and watches with seemingly limitless patience. But let an unwary grasshopper cross its vision, or even a thoughtless little sparrow venture too near, and instantly it dashes away in pursuit of the intended prey. Ruthless, cruel, and wasteful it is, and has fairly earned the reputation that its name "butcher-bird" implies; for, not content with killing for use, it carries on the work of slaughter as long as opportunity remains, and, after its appetite is sated, impales its further victims upon the long thorns of the desert shrubs or the barbs of the wire fences. Nor is this, even in such a land of famine, a wise

provision against future need, as might naturally be supposed, for seldom does the shrike return to these relics of its former successes save only in passing on some new foray. Its nest may be found hidden away in some bush, guarded by a veritable chevaux-de-frise of branches and formidable thorns; and if eggs or young are there the parent is well-nigh sure to appear close at hand in vigorous defense of its own, oftentimes approaching with apparent loss of all fear, scolding energetically the while.

Attractive alike in song, bright dress, and confiding ways, the house finch is particularly welcome in the desert. About the cliffs and rocky slopes, or among the cottonwoods along the streams, it is not less at home than when it comes around the ranch house or frequents the streets of the town with all the familiarity of the well-known house (English) sparrow. Though thus in some of its habits similar, yet it has few of the obnoxious traits of that pest. It builds its nest and rears its young about the house, under the eaves of sheds or barns, in walls, caves, or in any such place that gives promise of requisite convenience. Pleasant indeed it is, at early morning, ere the heat of the day has dried up the fountain of action, to stroll along at the foot of the rocks down to some tree-sheltered spring in the desert, and to hear from all around the many voices of the birds, as led by the house finch they join in matin chorus; an experience that seems not a little unexpected, and strangely at variance with the surroundings, but which for this reason all the more strongly emphasizes the thought it suggests, that contentment is a condition of mind rather than of environment—that the house finch is happy in spite of his living in the desert.

The bright starry night of the desert has its birds as well as the day. Scarcely has the darkness begun to fall before the poorwill may be heard mournfully calling from over the valley, or seen in the deepening twilight seeking the margin of the water or an open place in the brush in pursuit of its insect prey. Very like a huge moth it is, as it glides low on noiseless wing, flutters for an instant, drops to the ground and is lost to view. Owls, little and big, from time to time hoot in the hills. Among them is the giant great horned owl, whose nest may here be found perched on a crag, for the exigencies of a treeless country compel recourse to unusual nesting sites, and, like the large hawks, the owl takes to the rocks.

In the wider and higher valleys and on the far-extending plains where the "everlasting" sagebrush prevails, here but nowhere else the renowned sage grouse makes its home. Secure in the excellent protection that the brush affords, the bird rarely takes flight at the advance of a possible enemy until closely approached, when with a loud whirr it rises with apparently great effort until the tops of the

bushes are cleared; then on powerful wing it travels swiftly and far, at length sailing like the prairie hen and disappearing over a knoll or down into the monotonous expanse of sagebrush. At the nuptial season the curious actions of the male draw more than casual attention, as with tail spread, neck and fore-breast enormously inflated and thrown forward till they brush the ground, he moves pompously about. Besides the sage grouse, the sagebrush country has other avian inhabitants; the abundant, widely distributed lark sparrow starts up all along the roadside, displaying its prettily patterned tail as it flies, or from over in the brush regales the listener with its varied song; the more humble Brewer sparrow sings its melodious little lay, or, perhaps, too anxious, betrays the secret of its home in some near-by bush; the sage sparrow, becomingly attired in black, white, and gray, flits through the shrubbery or runs rapidly along the ground; the trim green-tailed towhee skulks elusively, almost mouse-like, under the bushes, or from some hidden perch sends forth its rhythmical notes; and the sage thrasher may be heard in vivacious song, or perchance seen unobtrusively leaving its well-hidden nest.

In the grass or rushes bordering the springs and ponds the little western savanna sparrow is often to be found at home, and among the tules or in the thickets along the streams the western yellow-throat and the song sparrow find congenial surroundings, though neither is by any means so common as in the East.

The wide expanse of the Great Salt Lake, its mountainous islands, its muddy or stony shores, the level lands along its borders, white with salt and alkali, and the fields in the valley, made fertile by the magic of irrigation, have each a particular attraction for birds. Graceful terns, ducks of many kinds, together with grebes, among them the pied-billed, frequent the open water or the marshes, while multitudes of wading birds range the beach and spread out over the flats. Down by the margin of the lake, over the meadows and the marshes, the bittern heavily fies, or stalks about in dignified, secretive, yet apparently nonchalant way, pausing now and then to utter, with curious, not to say painfully ridiculous, contortions, its hollow, strangely resonant notes, but ceasing and turning to a statue well-nigh invisible at the slightest hint of danger. The wild-eyed, wild-voiced, wild-mannered long-billed curlew guards its preserve along the lake with jealous care, and at any act of trespass pours forth a torrent of abuse that is intended to be very threatening, but under the circumstances is vastly amusing. There are bright-plumaged orioles in the cottonwoods; sparrows and yellow-throats in the thickets along the sloughs; house wrens about the dwellings; western meadowlarks that rise from the meadow where the bobolink soars and sings; and

big Swainson hawks that come and go high up in the blue ether. Some of the rocky islands that ascend precipitously hundreds of feet from the surface of the lake, dry and barren as for the most part they seem to be, support a bird population by no means inconsiderable, for here, among many, are the house finch; the brush-loving sage thrasher; those birds of the chaparral—the black-throated, Brewer, and lark sparrows; the well-known catbird of eastern thickets; the horned lark; the modest little flycatcher; the white-rumped shrike; and that lovable little songster, the warbling vireo.

The stranger in these deserts is at once impressed with the pallid vegetation, so fully in keeping with all around; but in the southern part of the Great Basin—in extreme southern Nevada, western Arizona, and southeastern California—this monotonous color tone is relieved by the dark, rich green of the shiny, resinous leaves of the handsome creosote bush, and in places by the great tree yuccas, whose branches, spread in strange, even fantastic, shapes, support a massive, spiny foliage.

Here, out in the brush, lives the Gambel partridge, often in great numbers. Ordinarily, if venturing from its chosen cover, it is ever alert for the signal of danger; but if unmolested it becomes in due time and place so unsuspicious that it is scarcely alarmed even when the passer-by is near at hand. The ash-throated flycatcher, unobtrusive, yet by reason of its abundance, conspicuous, is one of the most distinctive birds of the desert, and its mildly strident call is one of the common sounds. The active and excessively shy Leconte thrasher is far more difficult of acquaintance than some of its neighbors, but its delightful song and odd, interesting ways abundantly repay the painstaking observer. The cactus wren is particularly fond of the great tree yuccas and the tall cactuses, where his rough, globular nest is so much in evidence; but, modest architect that he is, he presents to view not himself but only his work. The far-famed mocking bird, too, so oft proclaimed the prince of singers, here “wastes his sweetness on the desert air,” but finds hardly so congenial a dwelling place as in some other climes. The Costa humming bird, midget though it is, defies the heat and the drought of the desert, living here in apparent happiness and comfort; the little yellow-headed verdin fashions its curious retort-shaped nest in the bushes, and, more provident than some of its fellows, repairs the same one for winter use or builds another; in the canyons leading into the hills and the mountains, where the strikingly attired phainopeplas congregate to chat and eat and the cliff swallows are busily engaged in their household cares at the colonies of their closely crowded homes on the rocky walls, the sweet-voiced canyon wren fills the air with ringing melody or, exulting in its impreg-

nable fortress, flings down a note of taunting defiance; the golden eagle, holding himself sternly aloof from his neighbors, wheels about his eyrie on the crag or, leaving it behind, soars majestically out over the valleys; and the Texas nighthawk, in its pursuit of insect prey, silently at dusk haunts the vicinity of the springs and lakes and streams.

Few places there are in this or any other country where desert conditions are more intensified than where, walled in by ranges of barren mountains and partly below the level of the sea, lies the famous Death Valley of California. Yet even here bird life is not wanting. The ubiquitous killdeer frequents each pool and stream and little marsh, and by its petulant cries, at times continued far into the night, makes itself known. The mourning dove, common in all the great West, is here so regular a visitor to the springs that its presence betokens almost with certainty the nearness of water. Here, too, that strangest of all strange birds of the desert, the road-runner, though shy and retiring, betrays itself now by tell-tale footprints in the sand, now by occasional distant fugitive appearances as it runs among the bushes or, with head and tail erect, pauses momentarily to survey its surroundings. The rough-winged swallow is found about the springs; the least vireo in some of the lower mountain canyons; once in a while a kingfisher wanders over into the valley; the powerful-winged white-throated swift comes down from its inaccessible home in the cliffs to hunt in the low country; vultures appear at times in search of their grewsome repast; and the hoarse croak of that sombre-hued bird of ill omen, the raven, is a familiar and peculiarly suggestive sound in this valley of solitude and death.

THE DIVISION OF INSECTS IN THE UNITED STATES NATIONAL MUSEUM.

By J. M. ALDRICH,
Associate Curator.

[With 15 plates.]

HISTORY.

The insect collection of the National Museum owes its beginning to Dr. C. V. Riley, who became Chief of the Division of Entomology in the Bureau of Agriculture in 1878. He brought with him from his nine years of great activity as State entomologist of Missouri a good working collection of the insects commonly met with at that time in economic work, as well as many others accumulated along with them. The Riley collection was formed with a very distinct practical object; as a standard with which to compare insects encountered in the daily work of an economic entomologist, in order to find out the extent of distribution of injurious forms, or to be sure that specimens referred to him for name were really the same as those which had proved to be injurious or beneficial. This sort of work, very elementary at first, gradually took on a more specialized character as the number of insects important in agriculture increased with the growth of economic entomology. The few assistants on Riley's staff took up various groups of insects for study in their available time, and by collecting added largely to what had been originally brought to Washington. In 1882 Riley deposited the collection for safekeeping in the National Museum (old building), and was designated honorary curator of entomology on the Museum staff.

In 1886, in consideration of the appointment of an assistant curator to be paid from Museum funds, Riley formally transferred the whole insect collection, then numbering some 115,000 specimens, to the Museum; as before, however, it continued to receive the attention of specialists in the division, and to serve the same economic purposes. The assistant chosen was John B. Smith, of Brooklyn, who remained about three years and then became State entomologist of New Jersey. After his departure the position was unfilled, but Martin Linell was appointed aid, continuing in this grade until his death in 1896.

Until Riley came to Washington the policy of the National Museum had been to distribute the entomological collections received to various specialists and to maintain no national collection of insects. Riley's predecessor, Townend Glover, had preserved specimens only for illustrating and identifying them; in consequence his remarkable work left but little impression upon the national collection.

Upon the foundation laid in 1886 as above indicated, the insect collection of the Museum has grown by the addition of material from many sources. The principal collections acquired through Riley's influence (up to 1895) were those of the following collectors:

John B. Smith (mostly Lepidoptera and Coleoptera).

Martin L. Linell (Coleoptera).

G. W. Belfrage (miscellaneous insects, mostly from Texas, but including Palaearctic Coleoptera and Hymenoptera).

H. K. Morrison (miscellaneous insects from Georgia, the White Mountains of New Hampshire, and the West; many named Coleoptera).

Asa Fitch, first State entomologist of New York (miscellaneous insects, with some types acquired long after his death).

Cyrus Thomas, State entomologist of Illinois (grasshoppers).

S. W. Williston (type collection of Syrphidae).

Geo. Marx (spiders and other arachnids).

C. H. Bollman (myriopods).

The sudden death of Riley in 1895, and the appointment of Dr. L. O. Howard, his successor in the Agricultural Department, as honorary curator in the Museum, was another point of importance in the history of the collection. Simultaneously with Howard's appointment several of his economic staff were designated as custodians in the Museum: Coquillett in Diptera, Ashmead in Hymenoptera, and Schwarz in Coleopterous Larvæ. O. F. Cook, of the Bureau of Plant Industry, was made custodian of myriopods. The meaning of these appointments was that the men were recognized as authorities in the groups under their charge, and were expected, while continuing on the pay roll of the Agricultural Department, to give much of their time to identifying insects sent in to the department; and in the intervals of this work they were to classify, improve, and increase the collections.

The entomological work of the Department of Agriculture increased rapidly from about this time; what had been called the Division of Entomology became a bureau shortly after. Its field stations with an enlarging number of workers brought ever larger quantities of material to Washington for identification, and this compelled a gradual increase in the number of custodians. In 1898 H. G. Dyar was put in charge of Lepidoptera; in 1899 Schwarz was given Coleoptera, and Banks, Arachnida. Others were added later. The completion of the new National Museum in 1908 afforded room for the staff, and the collections were segregated and placed in

several rooms. W. H. Ashmead was assistant curator from 1898 to 1907, H. G. Dyar for a few months, and J. C. Crawford from 1908 to 1911, and associate curator to 1919.

Under the administration of Dr. Howard, the principal collections added up to 1900 were the following:

The Hubbard and Schwarz collection, mostly Coleoptera and their larvæ; this was accompanied with the entomological library of the donors, rich in complete sets, which formed the foundation of the present library of the division.

The southern California collection of D. W. Coquillett, comprising mainly Diptera and Coleoptera, with some important Hymenoptera.

Additions since 1900 have been numerous and important, especially in Lepidoptera, Hymenoptera, and Hemiptera; but the limits of space forbid continuing the analysis further at present.

A few lines may, however, be given to foreign collections, in which the beginnings have been in general more recent. Some named foreign material was included in several of the collections noted above. In 1905-6 Busck and Knab collected in tropical North America under a grant from the Carnegie Institution, mosquitoes being the primary object, though insects in other orders were also secured in some numbers. In 1907 Busck collected in the Canal Zone under the auspices of the Canal Commission. In 1911 the Smithsonian Institution made a biological survey of the Canal Zone, in which Busck and Schwarz participated, Busck continuing the work the next year.

In the butterflies and moths of tropical America the Museum began to receive named material from William Schaus in 1901, the result of his own expeditions; his life work in this field has been generously devoted to the Museum, in recognition of which he was in 1919 made honorary assistant curator of insects.

Dr. W. L. Abbott began sending to the division his collections from tropical Africa and Asia as early as 1890, and has continued to the present, his many shipments running well into the thousands of specimens.

The custodians of various orders have in the last 20 years given increasing attention to exchanging as a means of acquiring named foreign insects, and through this method there is a constant growth of the foreign collection. The almost inconceivable number of kinds of insects in the world makes the undertaking a slow one, even to achieve here and there, for limited groups and for limited parts of the earth's surface, something approaching completeness.

FUNCTIONS.

The Division of Insects, as will appear from the preceding historical sketch, is organized on a cooperative basis. The Bureau of Entomology of the Department of Agriculture, which employs a very

large staff of entomologists in economic work throughout the United States, concentrates here the work of identifying the vast number of insects that are sent in. Such sendings come in large part from its own agents, but almost as many come from officials of the State experiment stations, and no small number originate with the general public. The staff of trained specialists which does this indispensable work is furnished by the Bureau of Entomology, which also turns over to the Museum each year some thousands of insects that have been reared or collected by its agents in the course of their investigations.¹ The Museum, on its part, provides an associate curator and two preparators, and working quarters for the staff, as well as furniture and fixtures, insect cabinets, and entomological supplies generally. The older specialists are designated by the Museum as honorary custodians of the various groups (several have been doing this work for periods of time extending from 15 to 40 years); they give such portions of their time as are not required in identification work to the general improvement and classification of the collection.

This system has resulted in the accumulation of a large and well-classified collection of the insects of the United States. Something has been done in getting together the insects of other countries also; but considering the enormous number of kinds of insects existing in the world, the foreign collection is still comparatively very small, and its increase is considered one of the foremost needs of the division.

The economic importance of having a large and well-classified collection of foreign insects might not be evident at first glance, but can be easily demonstrated.

Almost all the first-class insect pests that we have are foreign in their origin. Many have been traced back to very nearly the exact time and place of their entrance within our borders. A few of these may be cited to emphasize the point.

The gipsy moth, which has done great damage in New England, and is a source of some hundreds of thousands of dollars of expense every year, was introduced from Europe in 1869. The brown-tail moth, in the same region of the United States and only a little less injurious and expensive, came from Europe in 1893. The pink bollworm of cotton, for the eradication of which an elaborate campaign has been carried on for several years, was introduced from Egypt by way of Mexico, reaching the edge of the United States in 1915. The European pine sawfly (pl. 10) came into New England about 1914. The Japanese peach moth² came from Japan about 10 years ago. The European corn borer, which is making its way westward

¹ The Museum also receives material additions every year from the Bureau of the Biological Survey.

from the Atlantic coast, was introduced about four years ago. The cotton-boll weevil came from Mexico about 1892. The European pine-shoot moth was introduced about 1913. The Japanese beetle was discovered in New Jersey in 1916, and at present an expensive campaign of extermination is in progress, financed jointly by the State and the Federal Government.

To prevent other dangerous introductions, the Federal Horticultural Board was established a few years ago; among other activities, it has a system of inspection of vessels and cargoes at seaports. Insects found therein are sent to the staff at the Museum to determine whether they are likely to be of sufficient importance to justify condemnation proceedings or quarantine against shipments. Hence in the last analysis the Museum staff decides this vital question. But how are they to know? Evidently the efficiency of their work depends very much upon having access for purposes of comparison to a well-classified collection of the insects of the country involved.

Aside from the very direct economic object just mentioned, the study of insect life from a world viewpoint is desirable for another reason. The distribution of existing species of animals and plants throughout the world has been determined by the evolution of life under the conditions prevailing in the past and present. The laws of evolution can only be determined by prolonged study of existing and extinct forms. These laws must be of great importance to humanity; how great only the future can disclose. When Darwin, before publishing his *Origin of Species*, spent more than 20 years in patiently collecting the facts which would convince the world of the truth of his principle, he did not stop to calculate whether his work would have any economic results. He was interested in getting at the truth. Yet the most far-reaching benefits to humanity have come from the acceptance of the evolution point of view and more are to be expected as a fuller understanding of the laws of life is attained. Most of what we now know about human heredity has been entirely reorganized and given new significance through discoveries made by breeding experiments on certain flies (*Drosophila*). There are other great possibilities in the study of the lower forms of life. And in this study national lines have no existence; a world viewpoint is the only scientific one.

Adding to these considerations the further one that insects offer innumerable illustrations of exquisite beauty (as shown in slight degree by the colored plates accompanying this article), it may justly be said that there are reasons economic, scientific, and esthetic for the building up in the Nation's capital of a world collection of insects. This is the primary function of the Division of Insects.

* While this article was in preparation a specialist in the Museum identified another Japanese moth from within the United States for the first time, and it is now under further investigation.

Allied to this and almost a part of it, the Museum should furnish such conditions of safe preservation that private collectors would make it the ultimate repository of their collections. It is an indication of progress in this direction that the describing entomologists of the country are quite largely sending in their type material, or at least paratypes, without waiting to put the gifts in the form of a bequest.

To make its valuable material available to advanced students under regulations, liberal yet consistent with the permanent preservation of the specimens, is a third function. A large number of entomologists visit the Museum each year to study the collection.

To promote a popular interest in its field through exhibits, lectures, etc., is another very clear function. Owing to the fact that the personnel of the division is almost entirely derived from the Department of Agriculture and has duties primarily economic, but little has yet been accomplished in the direction last indicated.

INSTALLATION.

The Division of Insects now occupies eight rooms on the third floor of the New National Museum Building, with a total floor space of 6,150 square feet. The space assigned to the various orders is indicated on plate 1.

The pinned collections are kept in steel cabinets, constructed in units holding 50 glass-covered drawers in two columns of 25, each column having two detachable steel doors (pl. 2). The drawers are about 18 inches square, and are finished in two styles. In one case they are lined with compressed cork and the pins are inserted in this in the usual way; this method is used for butterflies and moths, dragon flies, and some other large insects. In the second style the drawer is unlined, but is filled with four columns of deep pasteboard trays of uniform width and multiple-unit length, which are cork-lined. Each species is kept in a tray by itself, which can readily be lifted out for study or for rearrangement; the number of specimens on hand of the species determines the length of the tray used for its reception.

Alcoholic material is kept in vials in tin-bottomed trays, labeled on the end.

Microscope slides are used for preserving lice, fleas, and some other groups where the size is small, as well as for extensive collections of dissected genitalia, other anatomical preparations, cast larval skins, mosquito larvæ, etc. This method of mounting seems to be increasingly in favor for small insects as higher powers of magnification gradually come into use.

Type material is recorded under a serial number, which is the same for all the specimens of a species. Each specimen bears a red

label with this number, and the word "Type," "Allotype," or "Paratype." In the Division of Insects the record of these numbers is in the sixth volume, and includes 22,969 numbers.

INVENTORY.

In 1886 Riley estimated the collection which he transferred to the Museum at more than 115,000 specimens. In his report for 1894 he estimates that the collection contained 45,000 species of insects, represented by 610,000 specimens. In 1901 Dyar announced by actual count 16,653 species and 129,789 specimens in the Lepidoptera. In 1905 in a special report Schwarz estimated the Coleoptera at 30,000 species. There appear to be no other estimates on file until June, 1919, when an effort was made to get an inventory of all the orders. On account of the magnitude of the task and the shortage of workers in some orders it was necessary to make estimates rather than absolute counts in some cases; these, however, were made from examination and are conservative. In summarizing below the results by orders, the items are reduced to two—the number of named species and the total number of specimens. Of these the former is by far the more significant, as a specimen may be anything from a duplicate housefly to a moth which a generous benefactor purchased for \$100 and presented to the Museum. In groups where single specimens are likely to have little value the figures have, however, been reduced to a very conservative basis—in scale insects, for instance, only specimens mounted on microscope slides are included.

Summary of collection, June, 1919.

Order.	Named species.	Total specimens.	Order.	Named species.	Total specimens.
Thysanura.....	¹ 100	¹ 700	Orthoptera.....	2,556	25,988
Odonata.....	705	16,642	Hemiptera.....	¹ 3,876	¹ 244,637
Isoptera.....	173	¹ 100,000	Lepidoptera.....	30,653	275,920
Ephemeraida.....	647	14,721	Diptera.....	10,253	210,880
Plecoptera.....			Siphonaptera.....	¹ 130	¹ 432
Corrodentia.....			Coleoptera.....	¹ 32,500	¹ 738,000
Mecoptera.....			Hymenoptera.....	17,638	493,757
Trichoptera.....			Thysanoptera.....	200	750
Neuroptera.....	¹ 125	¹ 1,250	Strepsiptera.....	159	414
Mallophaga.....			Total.....	98,925	2,125,189
Dermoptera.....	180	1,098			

¹ Estimated.

The collection is unique among those of the great museums in the large number of immature stages which it includes; this is a natural result of the immense amount of biological work on insects carried

on by the closely related Bureau of Entomology. Material illustrating life histories, the interrelations of insect species through parasitism and otherwise, and other biological phases of insect life is constantly accumulated by bureau workers; and after having served its immediate purpose as a basis for economic bulletins it is deposited in the Museum. Thus there has been accumulated a biological collection which in parasitic Hymenoptera and Diptera, and probably in some other groups, far surpasses that of any other Museum in quantity of reared material.

The fact that all of the Museum staff in the division have been more or less occupied with the rearing of insects in the course of economic studies has always kept the biological side uppermost in the division.

PERSONNEL.

(April 1, 1920.)

Administrative:

L. O. Howard, honorary curator.³

J. M. Aldrich, associate curator.

William Schaus, honorary assistant curator.³

Specialists:

In Coleoptera—

E. A. Schwarz, honorary custodian.³

H. S. Barber.³

Adam Böving (larvæ).³

F. C. Craighead (larvæ).³

W. S. Fisher.³

In Lepidoptera—

H. G. Dyar, honorary custodian.⁴

August Busck.³

William Schaus.³

Carl Heinrich.³

In Orthoptera—

A. N. Caudell, honorary custodian.³

In Hymenoptera—

S. A. Rohwer, honorary custodian.³

A. B. Gahan.³

R. A. Cushman.³

William M. Mann.³

L. H. Weld.³

In Hemiptera—

E. H. Gibson, honorary custodian.⁴

E. R. Sasser, scale insects.³

A. C. Baker, plant lice.³

Harold Morrison, scale insects.³

In Odonata and other Neuropteroids—

R. P. Currie, honorary custodian.³

³ On the Bureau of Entomology staff.

⁴ Voluntary, donating their services.

³ On the Bureau of Plant Industry staff.

In Diptera—

J. M. Aldrich, custodian.

Charles T. Greene, honorary assistant custodian.²H. G. Dyar, mosquitoes.⁴

In Isoptera—

T. E. Snyder.³

In Arachnida—

H. E. Ewing.³

In Myriopoda—

O. F. Cook, honorary custodian.³

In addition to the scientific staff as listed, there are 10 preparators and clerical helpers furnished by the Bureau of Entomology and two furnished by the Museum.

ILLUSTRATIONS.

Since the division, owing to the peculiarity of its organization and the nature of its material, is not able to reach the public to any great extent with exhibits up to the present, a few plates have been specially prepared from Museum specimens to accompany this article. Some of these represent groups of insects from a local standpoint with notes on habits; other plates show related insects from a distant region or from scattered localities. Species of beautiful colors or striking form have to some extent been favored in making the selections, and it has not been thought inconsistent with a popular aim to include many rarities which have never before been figured. Acknowledgment is made to the Bureau of Entomology for the services of Mr. Snodgrass and Miss Carmody.

EXPLANATION OF PLATES.

PLATE 1.

Ground plan of rooms occupied by the Division of Insects, on the third floor of the new National Museum.

PLATE 2.

One steel cabinet unit, open to show drawers containing the pinned insects. Below, one drawer filled with unit trays for small insects; another containing large insects not in unit trays.

PLATE 3.

Eurycantha horrida Boisd. From New Guinea. Natural size. Belongs to the walking-stick family of the order Orthoptera. The specimen is a female, and this sex has not heretofore been figured.

² On the Bureau of Entomology staff.

³ On the Bureau of Plant Industry staff.

⁴ Voluntary, donating their services.

PLATE 4.

Additional orthopterous insects. Natural size.

1. *Stilpnochlora coulouiana* Sauss. A katydid from Florida.
 2. *Plagiostira albonotata* variety *brevipes* Caud. A katydid with rudimentary wings, from Arizona.
 3. Eggs of No. 1, attached to a twig. Florida.
 4. *Archimandrita marmorata* Stoll. A cockroach from Nicaragua.
 5. Young specimen of No. 4, from Costa Rica.
- NOTE.—Nos. 1, 2, and 3 not previously figured.

PLATE 5.

Dragonflies (order Odonata). Natural size.

1. *Calopteryx splendens* Harris, male, from Spain.
2. *Rhinocypha fenestrella* Rambur, male, from lower Siam.
3. *Libellula cyanea* Fabr., female, from Maryland.
4. *Agrion dimidiatum* variety *apicale* Burm., male, from Maryland.
5. *Argia fumipennis* Burm., male, from Florida.
6. *Pseudoleon superbus* Hagen, female, from Arizona. A Central American species ranging northward to our Southwest.
7. *Nannothemis bella* Uhler, female, from Maryland.
8. *Perithemis domitia* Drury, female. The specimen is from Maryland, but the species occurs widely in tropical and eastern North America.
9. *Celithemis elisa* Hagen, female, from Maryland.

PLATE 6.

Neuropteroid insects. Natural size.

1. *Stilbopteryx costalis* N. An ant lion from West Africa.
2. *Ascalaphus ramburi* McLachl., from Japan.
3. *Panorpa nuptialis* Gerst. A scorpion fly from Texas.
4. *Polystoechotes punctatus* Fabr., from California.
5. *Acanthaelisis americana* Drury. An ant lion from Virginia.

PLATE 7.

Two-winged flies (order Diptera) of the family Bombyliidae. Members of this family are parasitic in the larval stage upon other insects. All natural size.

1. *Ezoprosopa pueblensis* Jaenicke, from Mississippi; occurs southward to Central America.
2. *Ezoprosopa capucina* Fabricius, from Germany.
3. *Hyperalonia hcla* Erich., from Mexico; occurs in Guiana.
4. *Ezoprosopa limbipennis* Macquart, from Canal Zone.
5. *Bombylius punctatus* Fabr., from Dalmatia.
6. *Bombylius discolor* Mikan. from Europe.
7. *Ezoprosopa dorcadion* Osten Sacken, from Utah.
8. *Ezoprosopa fascipennis* Say, from Utah.
9. *Hyperalonia gargantua* Knab, from Jamaica. Type.
10. *Hyperalonia latreillei* Macquart, from Guatemala.
11. *Hyperalonia cerberus* Fabr., from Porto Rico.
12. *Spogostylum pluto* Wied., from Mount Washington, N. H.
13. *Hyperalonia tantalus* Fabr., from Java.
14. *Anthrax abbreviata* Wied., from Paraguay.

PLATE 8.

Conspicuous beetles (order Coleoptera) from the vicinity of Washington, D. C.
Natural size.

1. *Scaphinotus shoemakeri* Leng. A bluish-bronzed beetle found rarely in the wooded ravines of Rock Creek Park and along the Virginia shore of the Potomac above the city; adults are found in September. They feed on snails.
2. *Calosoma scrutator* Fabr. A tree-climbing, green "caterpillar hunter," often abundant in early summer.
3. *Alaus oculatus* Linn. The "eyed elater," the most conspicuous of our native "snapping beetles," whose larvae follow and prey upon the young of wood-boring beetles. The black spots are, of course, not the eyes, which are situated on the head.
4. *Dorcus parallelus* Say. One of the less common stag beetles, family Lucanidae.
5. *Acanthocinus nodosus* Fabr. A gray and black "long horn" beetle, whose larvae develop under bark of pine, and whose protective coloration makes the adult almost invisible when resting in the crevices of pine bark.
6. *Osmoderma scabra* Beauv. A scarabaeid breeding abundantly in the decayed contents of hollows in the trunks of living deciduous trees. Sometimes called "Russia-leather beetle," because of the similarity of its strong but not unpleasant odor.
7. *Merinus laevis* Oliv. A dull black beetle breeding in rotten logs; the larva resembles a wireworm.
8. *Lucanus elaphus* Fabr. A stag beetle, very rare in the vicinity, but more abundant in the Middle States. The females have small jaws.
9. *Lucanus dama* Thunb. The common stag beetle. The female also has small jaws. The larvae are "white grubs," and live under old hardwood logs or stumps.
10. *Passalus cornutus* Fabr. The "Betsy bug." Occurs commonly in galleries in the soft outer wood of decaying deciduous logs, and is unique among beetles in that the pair of adults are supposed to attend and care for their young. Both adults and young are able to squeak.
11. *Pinotus carolinus* Linn. The largest native "tumble bug." It flies about at night and is often attracted to lamplight.

PLATE 9.

Beetles (order Coleoptera) photographed by H. S. Barber.

- 1, 1a, 1b. *Paratyndaris chamaeleonis* Skinner, from Brownsville, Texas. Enlarged nearly six diameters. Adults occurred on the shrub *Condalia obovata*.
2. *Lycostomus lateralis* Melsh. Male, from Paradise Key, Florida. Enlarged nearly six diameters.
- 3, 3a. *Cossonus hubbardi* Schwarz. Type. Tucson, Arizona; the larvae live in dead giant cactus. Enlarged nearly six diameters.
- 4, 4a. *Chionanthobius schwarzi* Pierce. Potomac River above Washington, District of Columbia (the type locality); breeds in fruit of fringe tree, *Chionanthus virginica*. Enlarged about eight diameters.

PLATE 10.

European pine sawfly, *Diprion simile* Hartig. Order Hymenoptera. Upper, female; lower, male. Connecticut. This insect has been introduced into New England in recent years. From drawings by Miss Mary Carmody. Greatly enlarged.

PLATE 11.

Hymenoptera of various families. Drawn by Miss Mary Carmody. All greatly enlarged.

1. *Helcostizidea xanthognatha* Rohwer, a parasite of wood-boring beetles. Montana.
2. *Lagarotis diprioni* Rohwer, a parasite of sawfly larvæ. Found in Virginia and Ohio.
3. *Euura macgillivrayi* Rohwer, a gall-making sawfly. Colorado.
4. *Dibrachys nigrocyanus* Norton, a parasite of sawfly cocoons. Widely distributed in the United States.
5. *Spathius similimus* Ashmead, a parasite of wood-boring beetle larvæ. Found in West Virginia and New York.
6. *Alloporus tomosiae* Rohwer, a parasite of wood-boring beetle larvæ. Virginia.

PLATE 12.

Moths (order Lepidoptera) from tropical America, of the family Cossidæ. The larvæ are all borers in wood. None of the moths on this plate have been figured before, and the specimens photographed are nearly all types of new species. All natural size.

1. *Givira gabriel* Dyar. Type. From Mexico.
2. *Givira tigrata* Schaus. Type. Costa Rica.
3. *Givira sandelphon* Dyar. Type. Mexico.
4. *Hypopta polybia* Schaus. Guatemala.
5. *Lentagenia tristani* Schaus. Type. Costa Rica.
6. *Givira nudaria* Schaus. Type. Venezuela.
7. *Prionoxystus duplex* Schaus. Type. French Guiana.
8. *Hemipecten gaudeator* Schaus. Type. Costa Rica.
9. *Cossus infantilis* Schaus. Type. Costa Rica.
10. *Costria corita* Schaus. Type. Colombia.
11. *Hemipecten cossuloides* Schaus. British Guiana.
12. *Hemipecten maruga* Schaus. Dutch Guiana.
13. *Psychogena miranda* Schaus. Type. Costa Rica.
14. *Hemipecten alfaræ* Schaus. Guatemala.
15. *Toronia adolescens* Dyar. Type. Panama.
16. *Lentagenia plagiata* Schaus. Costa Rica.

PLATE 13.

Miscellaneous insects, painted by R. E. Snodgrass. All natural size.

1. *Paraphyes laetus* Fabr. Panama. A "true" bug (order Hemiptera), allied to the squash bug.
2. Male dragon fly (order Odonata) from New Guinea. In the female of this species the hind wings are of the same color as the front ones.

3. *Pepsis completa* Smith. Paraguay. A digger wasp (order Hymenoptera).
4. *Heliasius benjamini* Caudell. Type. Arizona. A grasshopper (order Orthoptera).
5. *Pantophthalmus vittatus* Wied. French Guiana. A tropical two-winged fly (order Diptera).
6. *Micadina phluctanoides* Rehn. Type. Japan. A walking stick (order Orthoptera).
7. *Caupolicana fulvicollis* Spin. Chile. A solitary bee (order Hymenoptera).
8. *Margasus afzeli* Stal. Gaboon. Africa. A predaceous bug (order Hemiptera).

PLATE 14.

American tropical moths (order Lepidoptera). Natural size. Painted from nature by R. E. Snodgrass. None of these have been illustrated before.

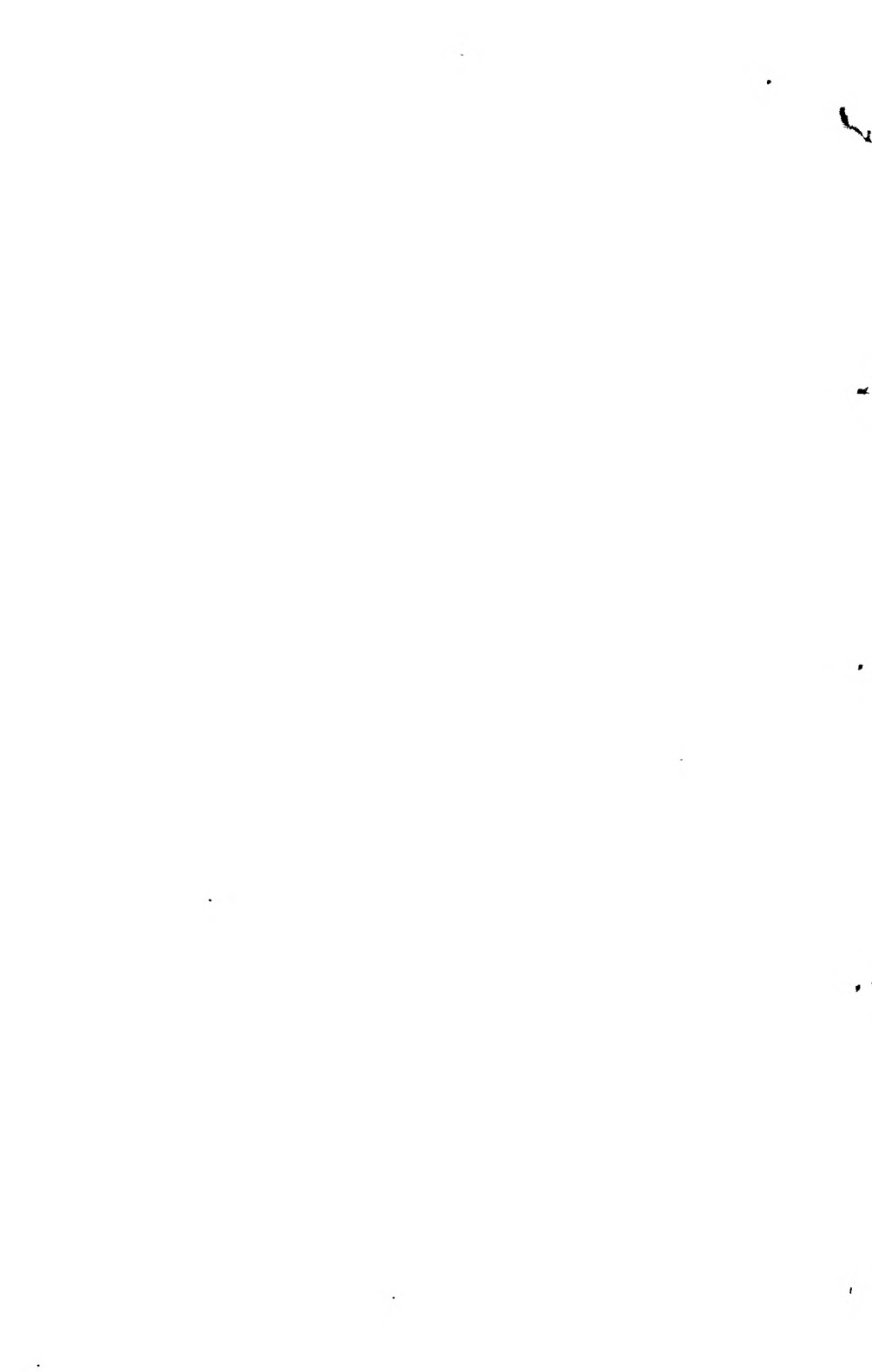
1. *Carthara oazacana* Schaus. Mexico.
2. *Rosema magniplaga* Schaus. Type. French Guiana.
3. *Cossula coerulescens* Schaus. Costa Rica.
4. *Amazia carinosa* Schaus. Type. Guatemala.
5. *Cercopimorpha sylva* Schaus. Type. Guatemala.
6. *Automeris sinaloensis* Schaus. Mexico.
7. *Claphe palota* Schaus. Southeast Brazil.
8. *Lysana caudatula* Schaus. Guatemala.

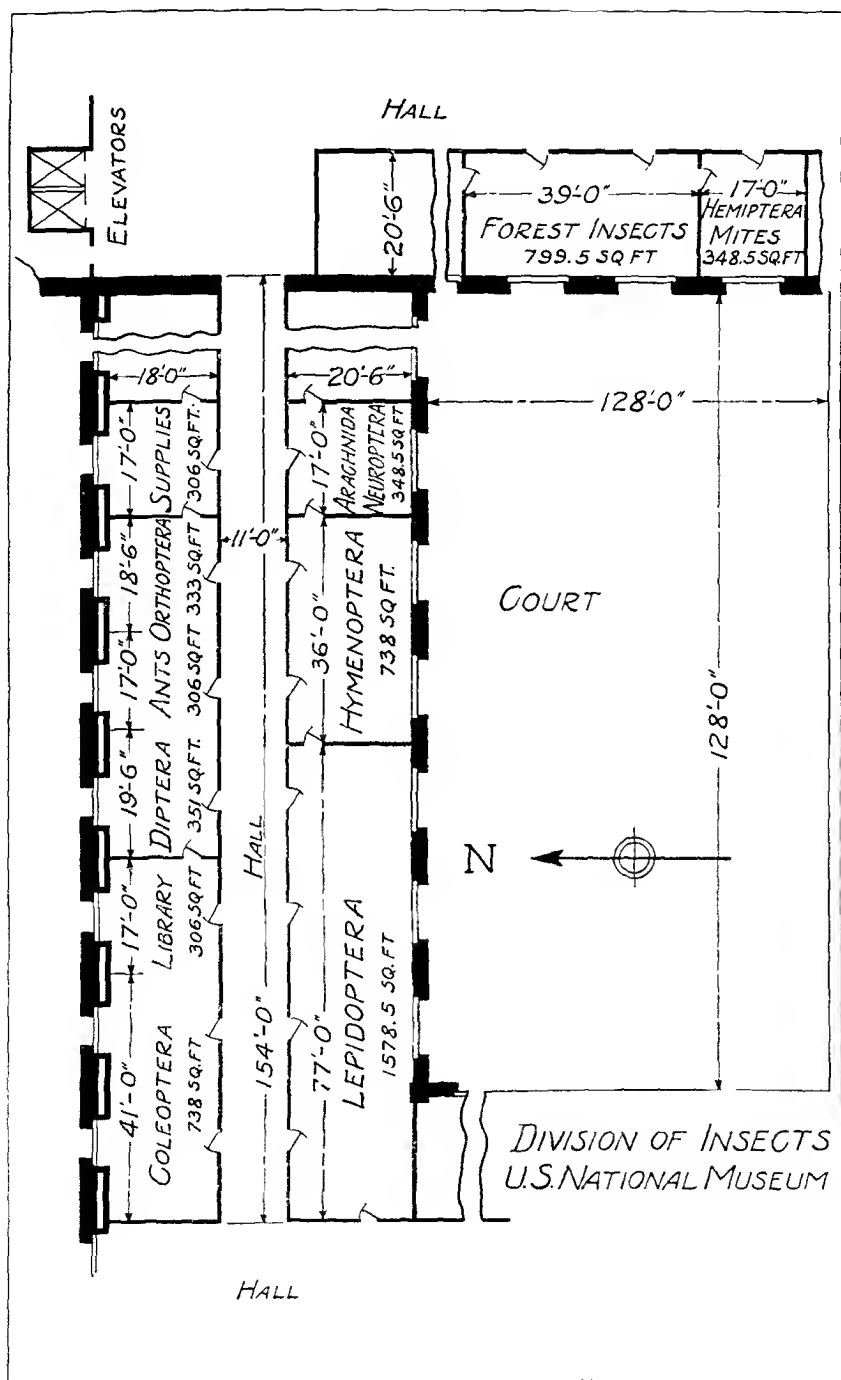
PLATE 15.

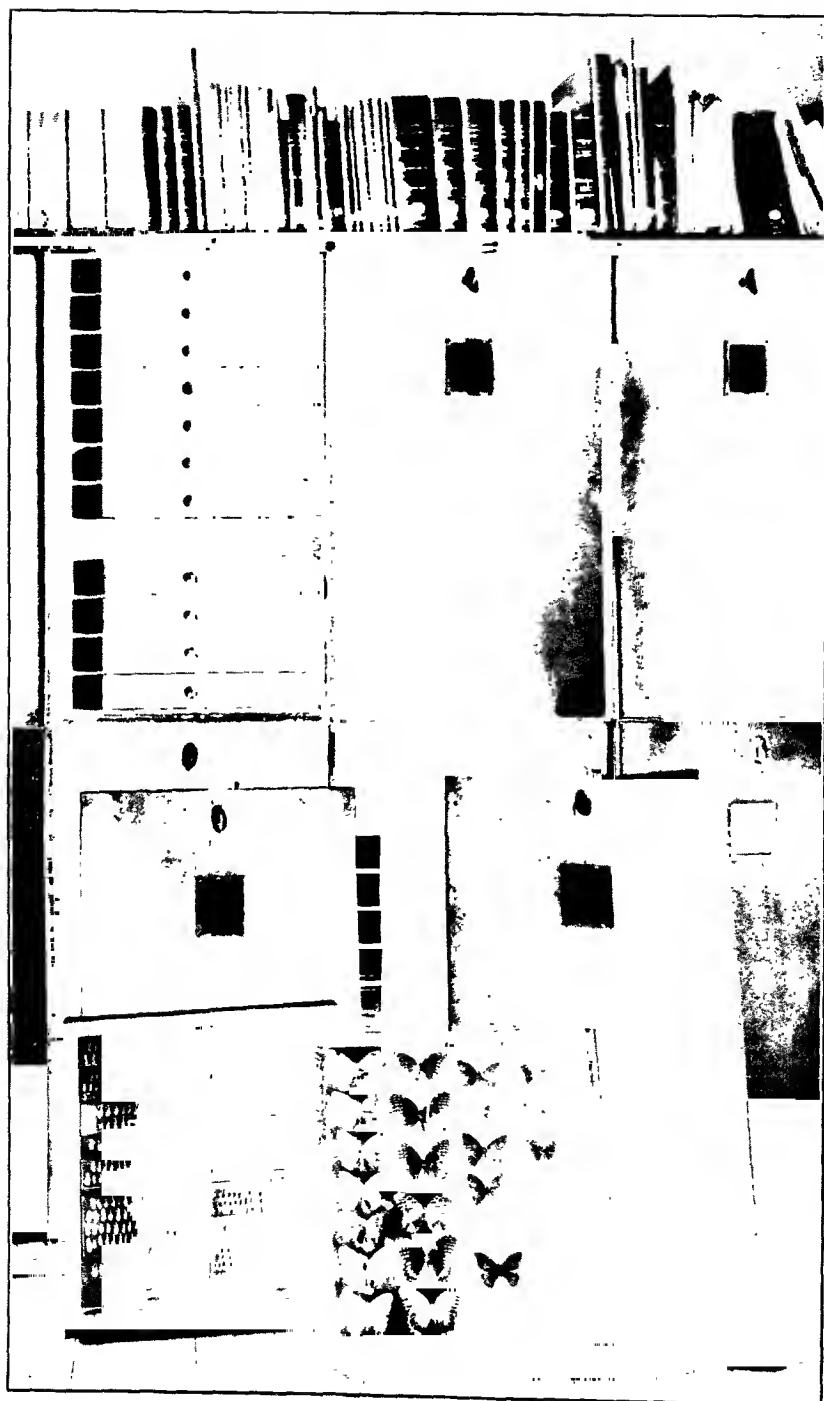
American tropical moths. Natural size. Painted by R. E. Snodgrass. Neither has been illustrated before.

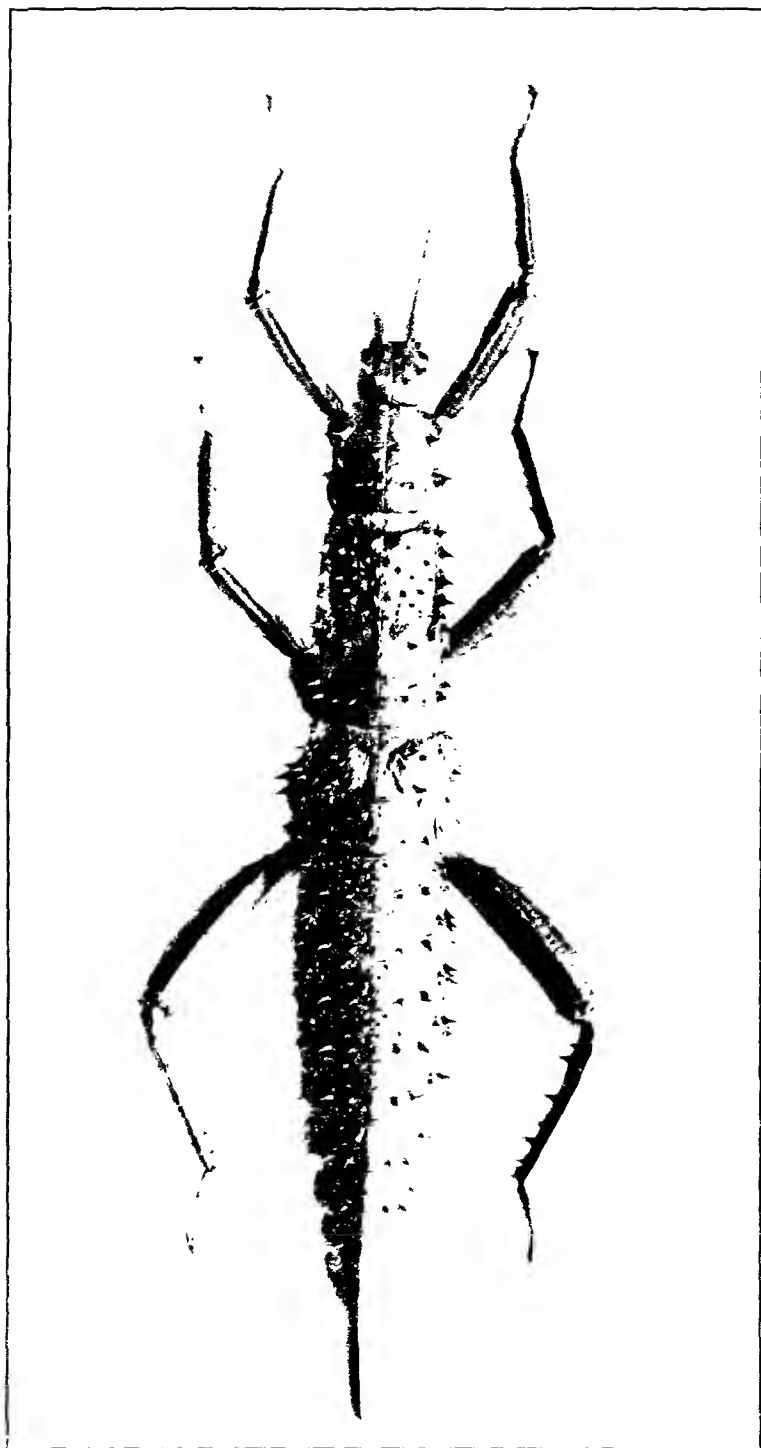
Upper figure, *Heliconisa arpi* Schaus. Type. (*H. sutanas* E. D. Jones.) Southeast Brazil.

Lower figure, *Dirphia carminata* Schaus. Type. Mexico.

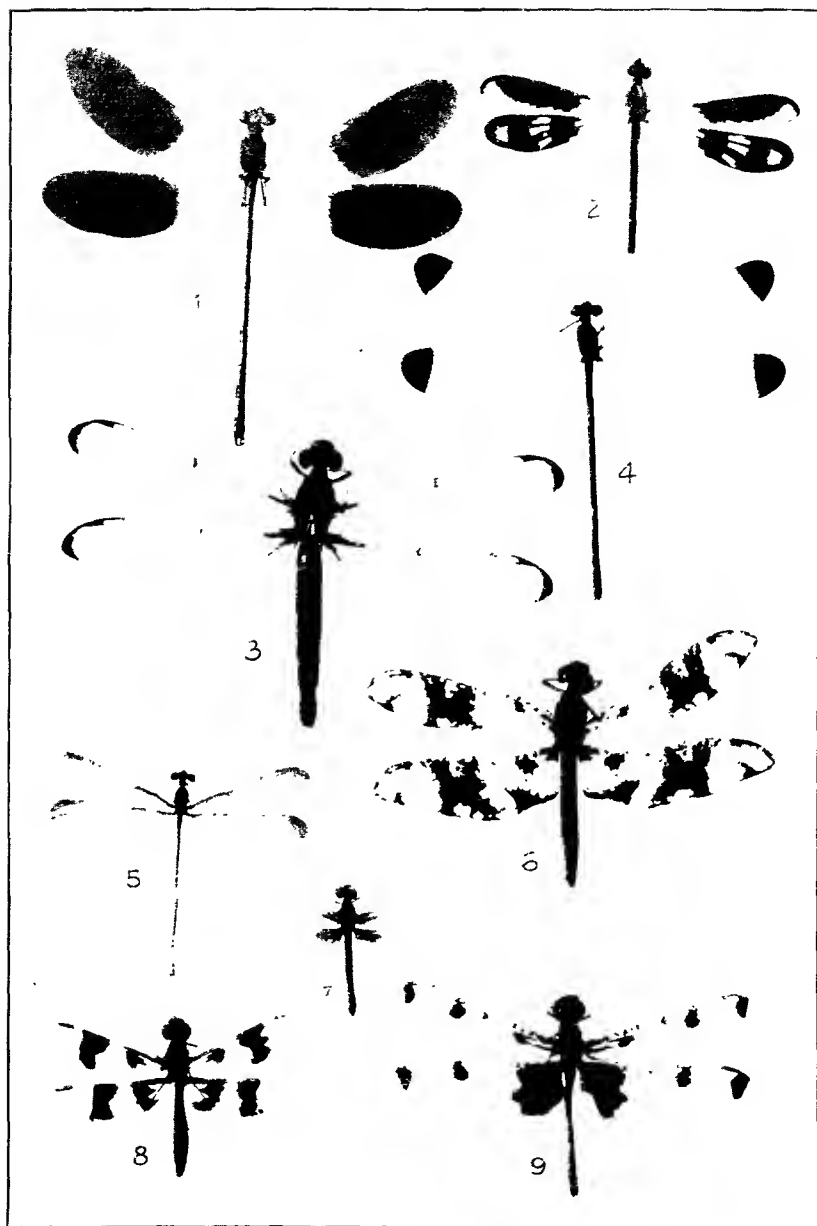




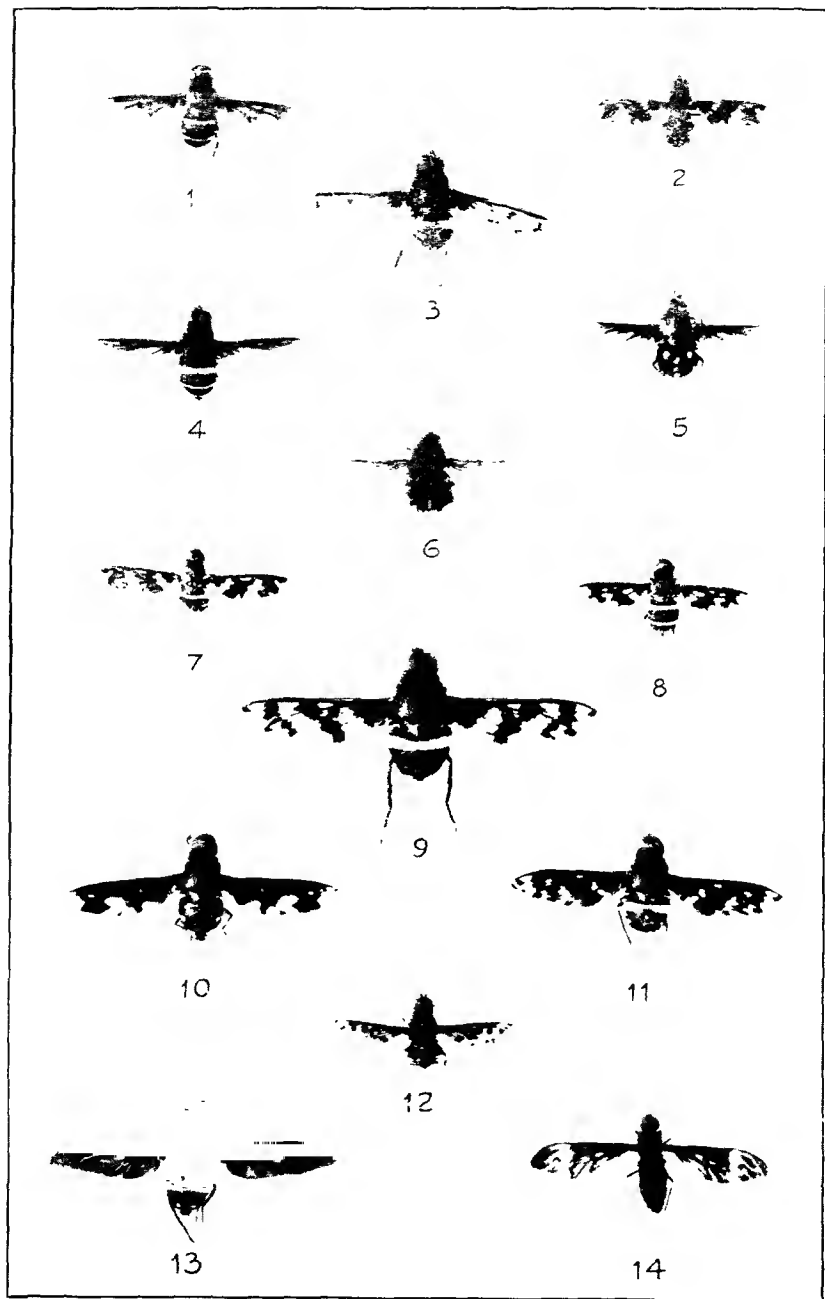


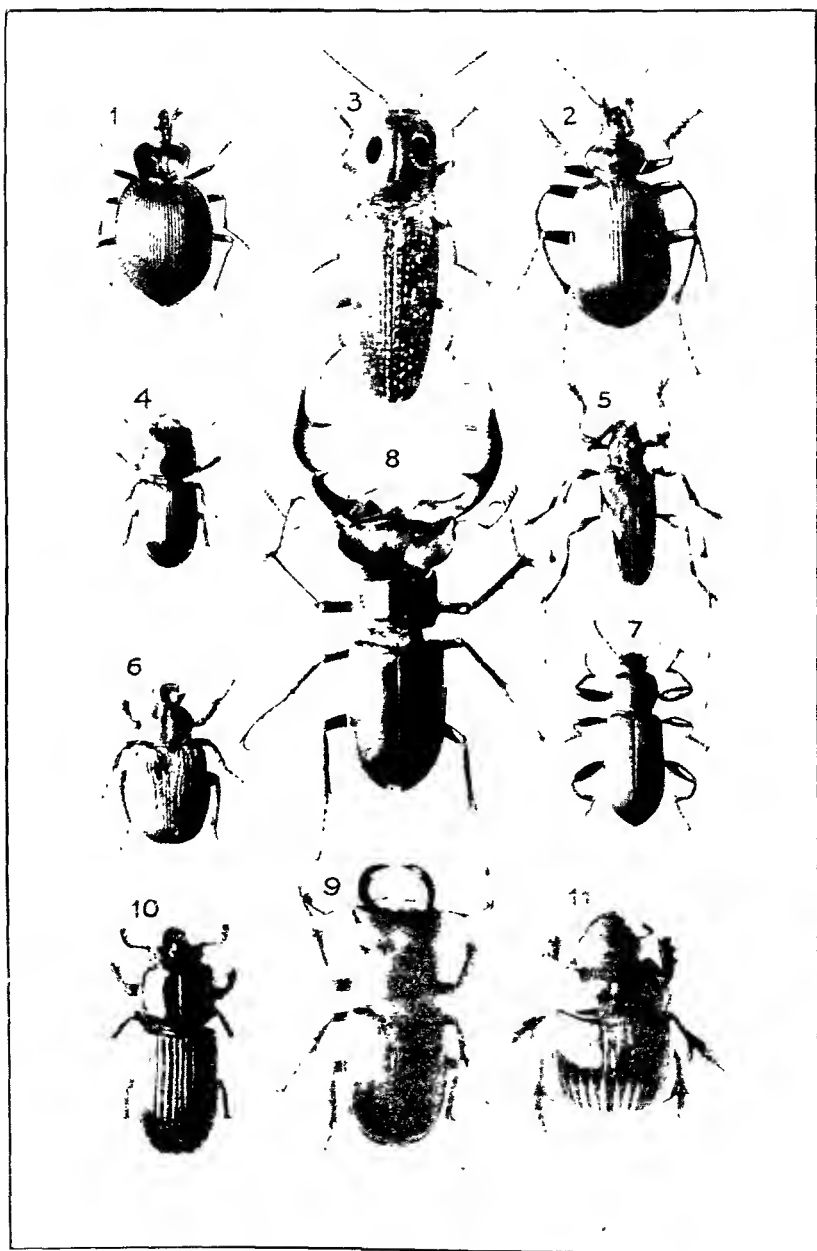




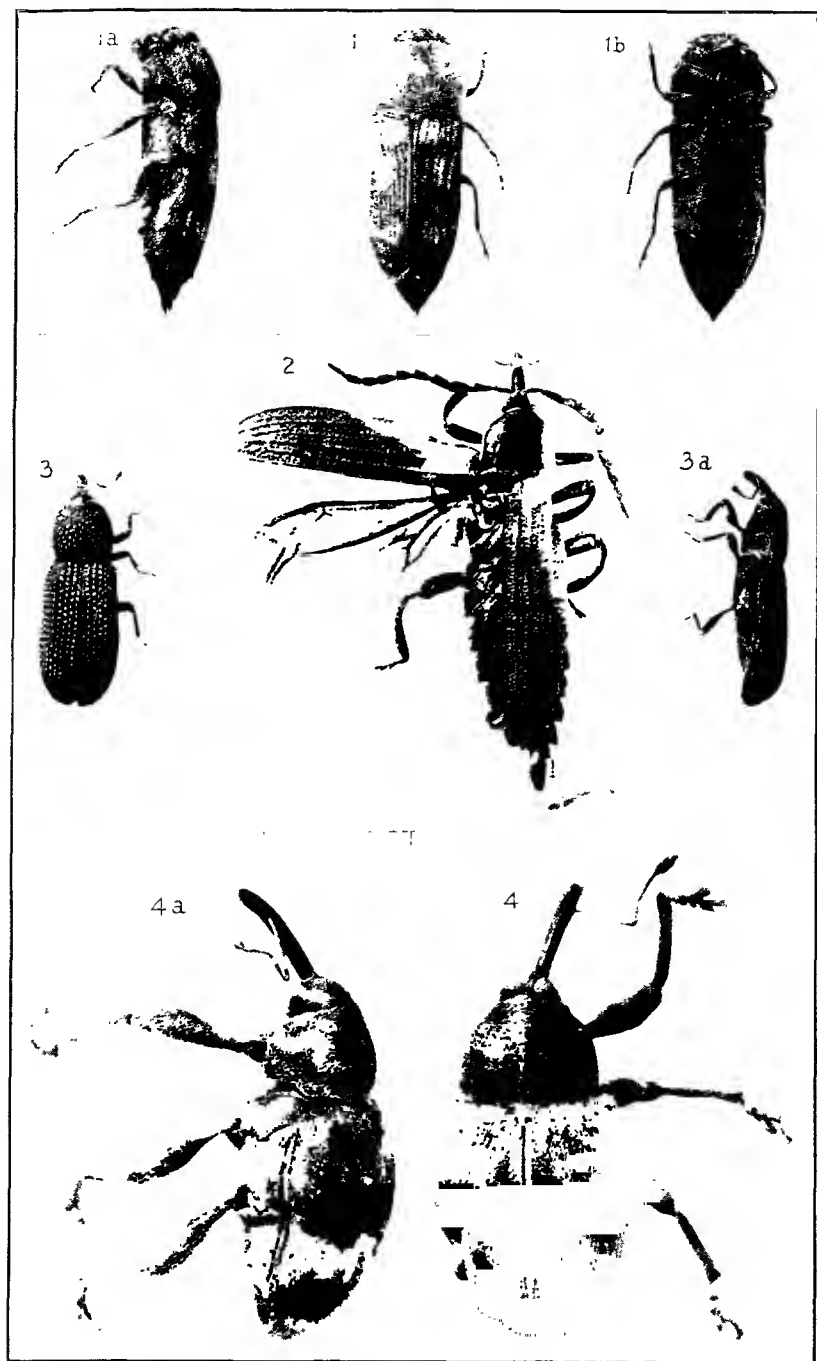


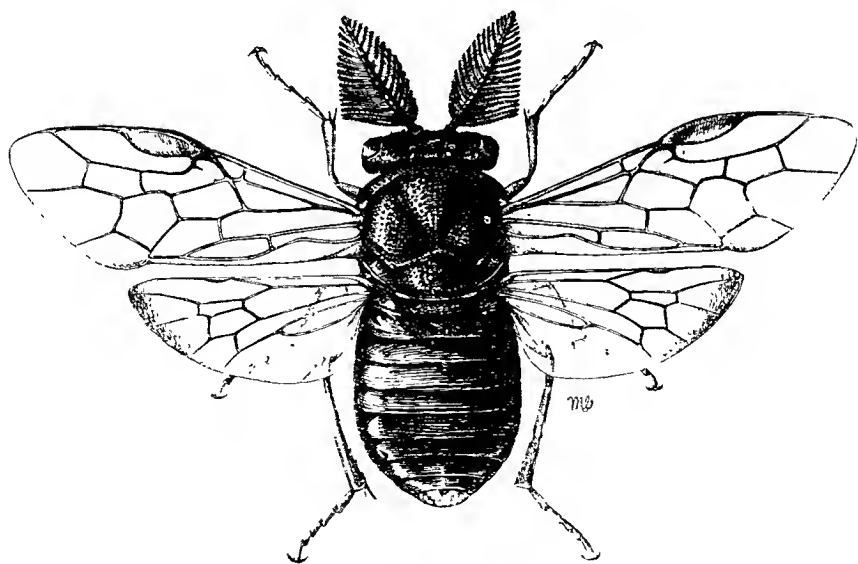
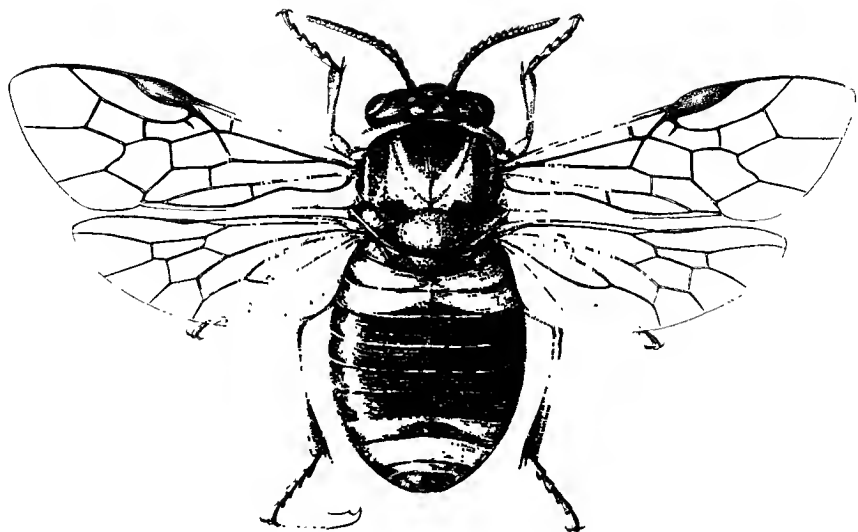




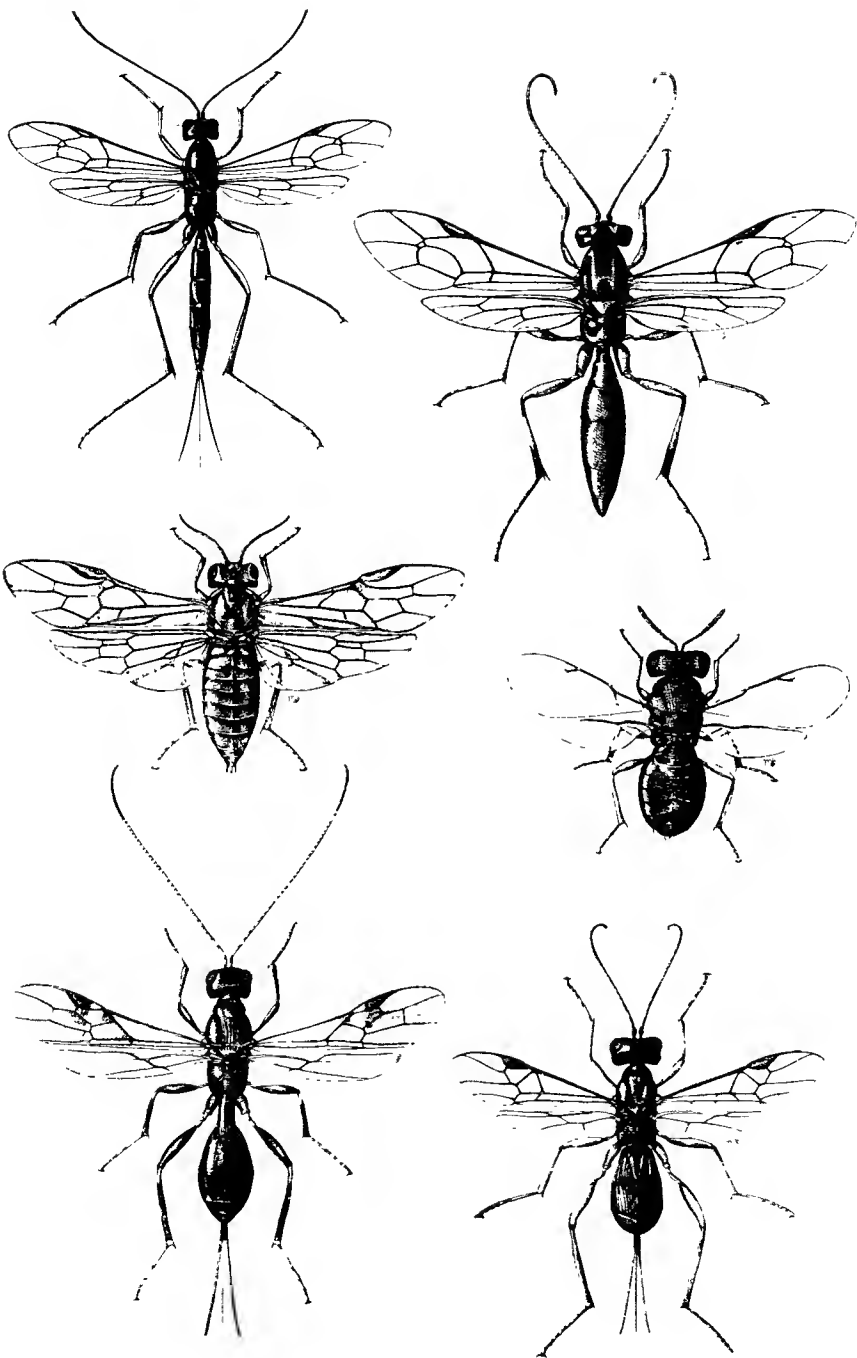


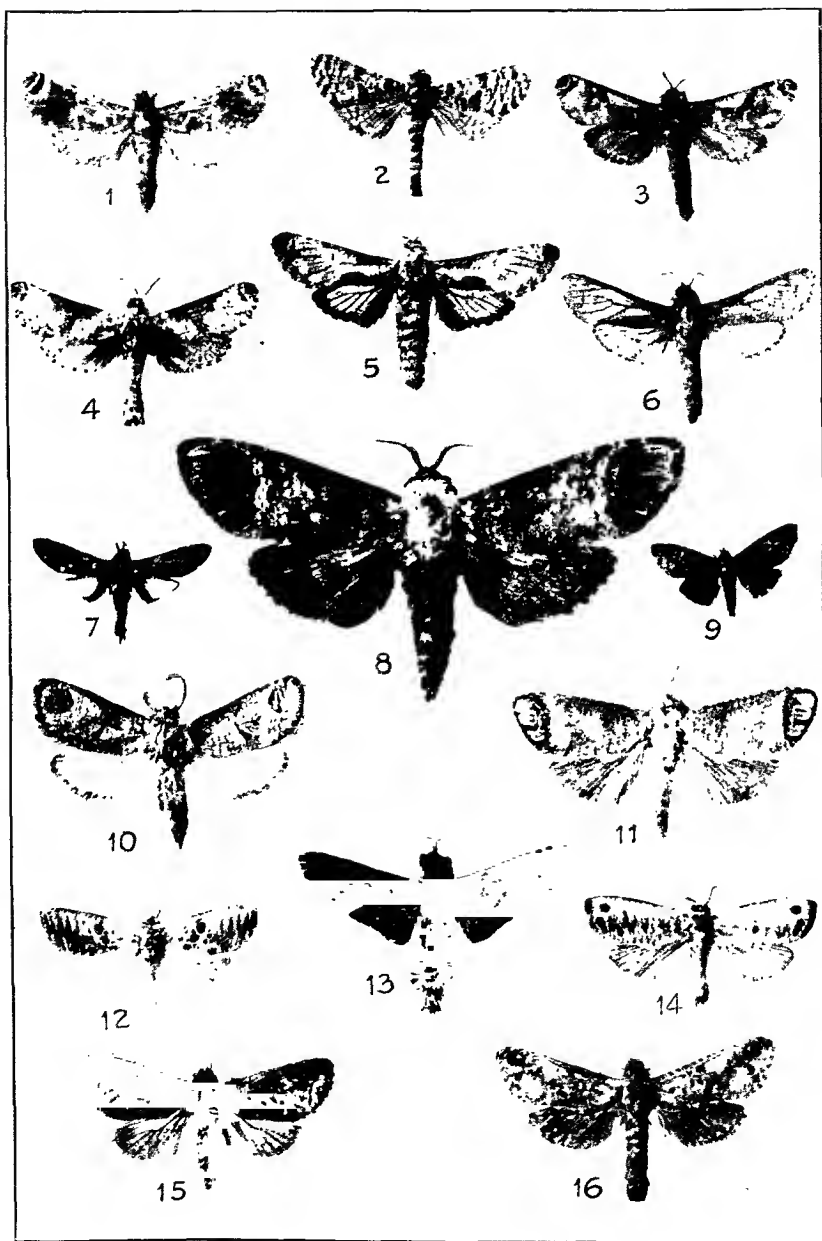
FOR EXPLANATION SEE PAGE 377.

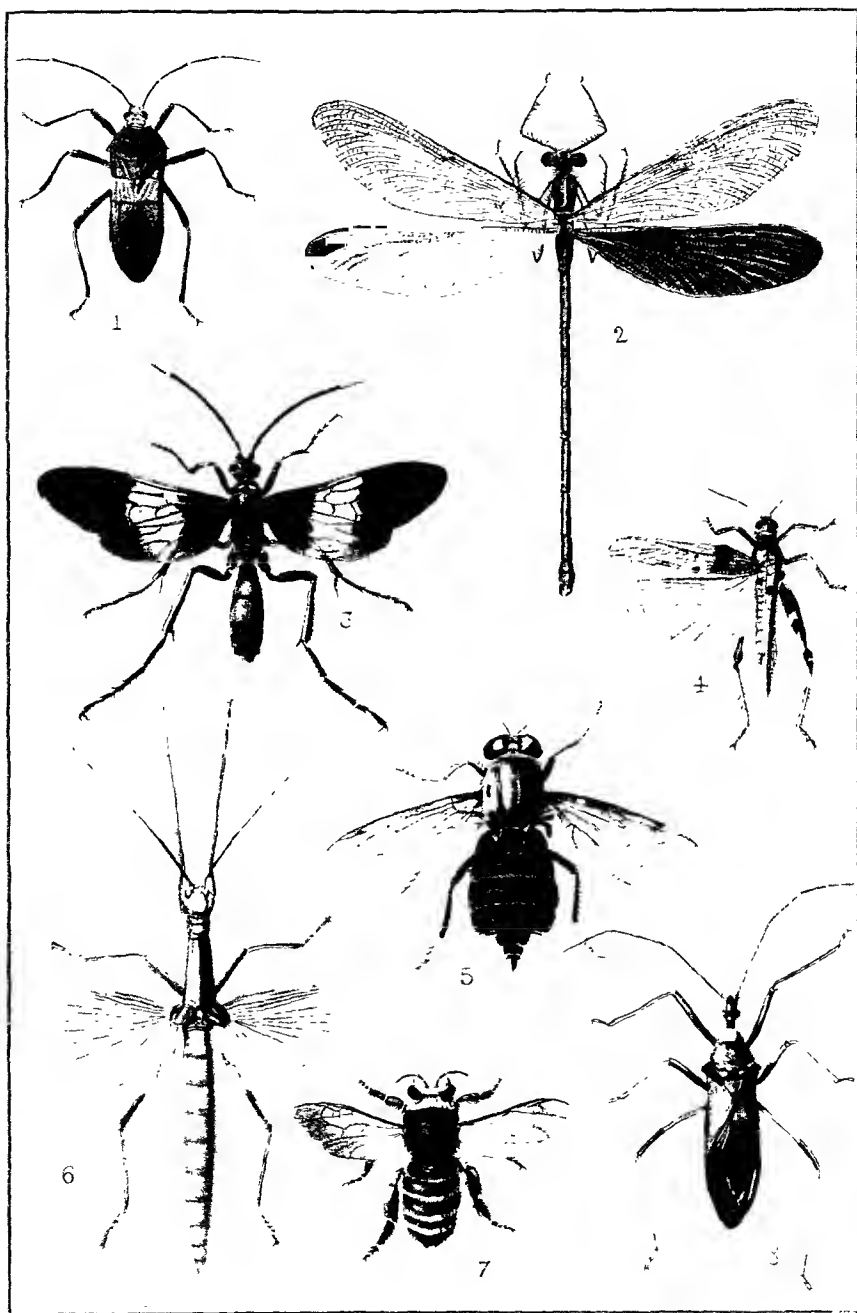


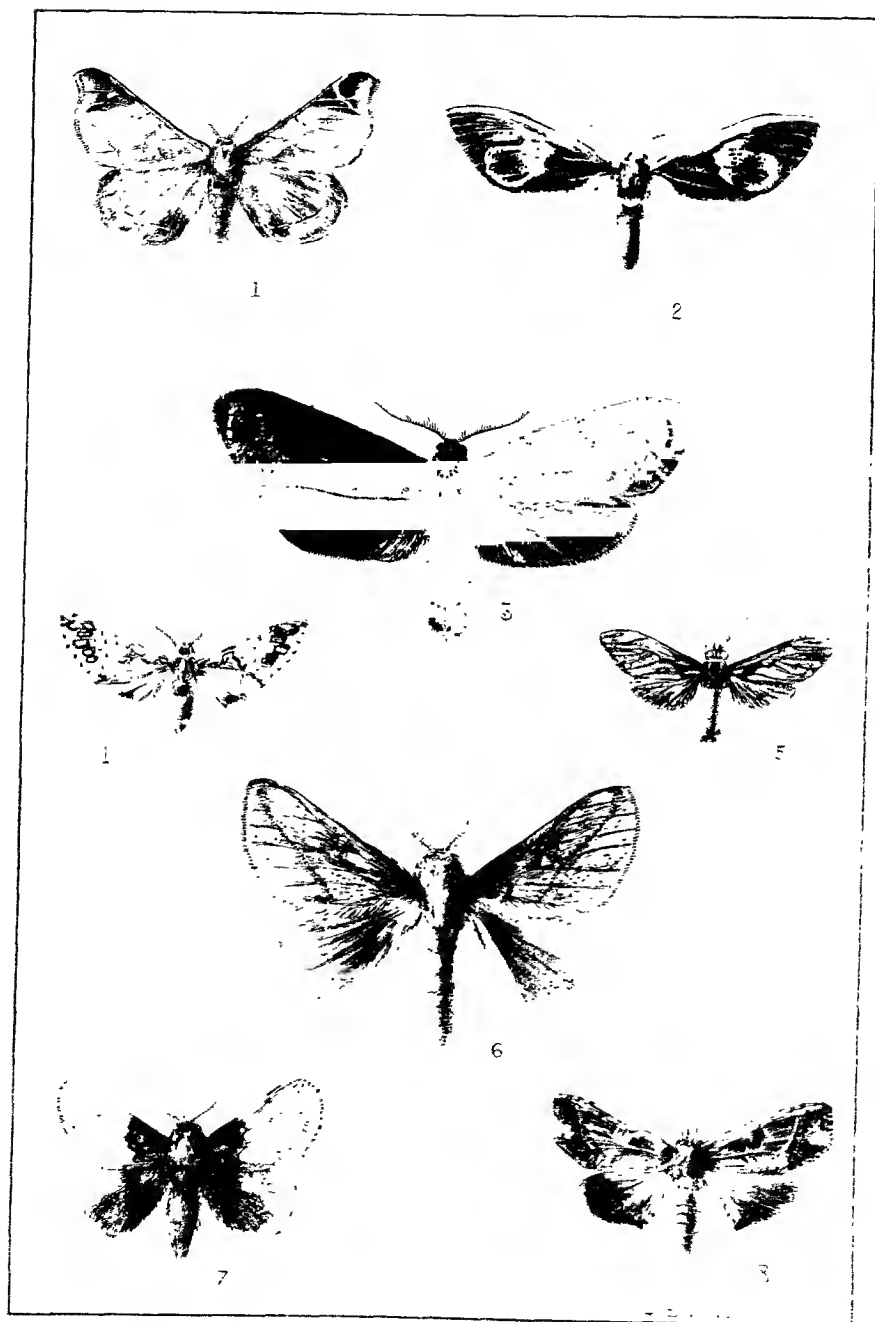


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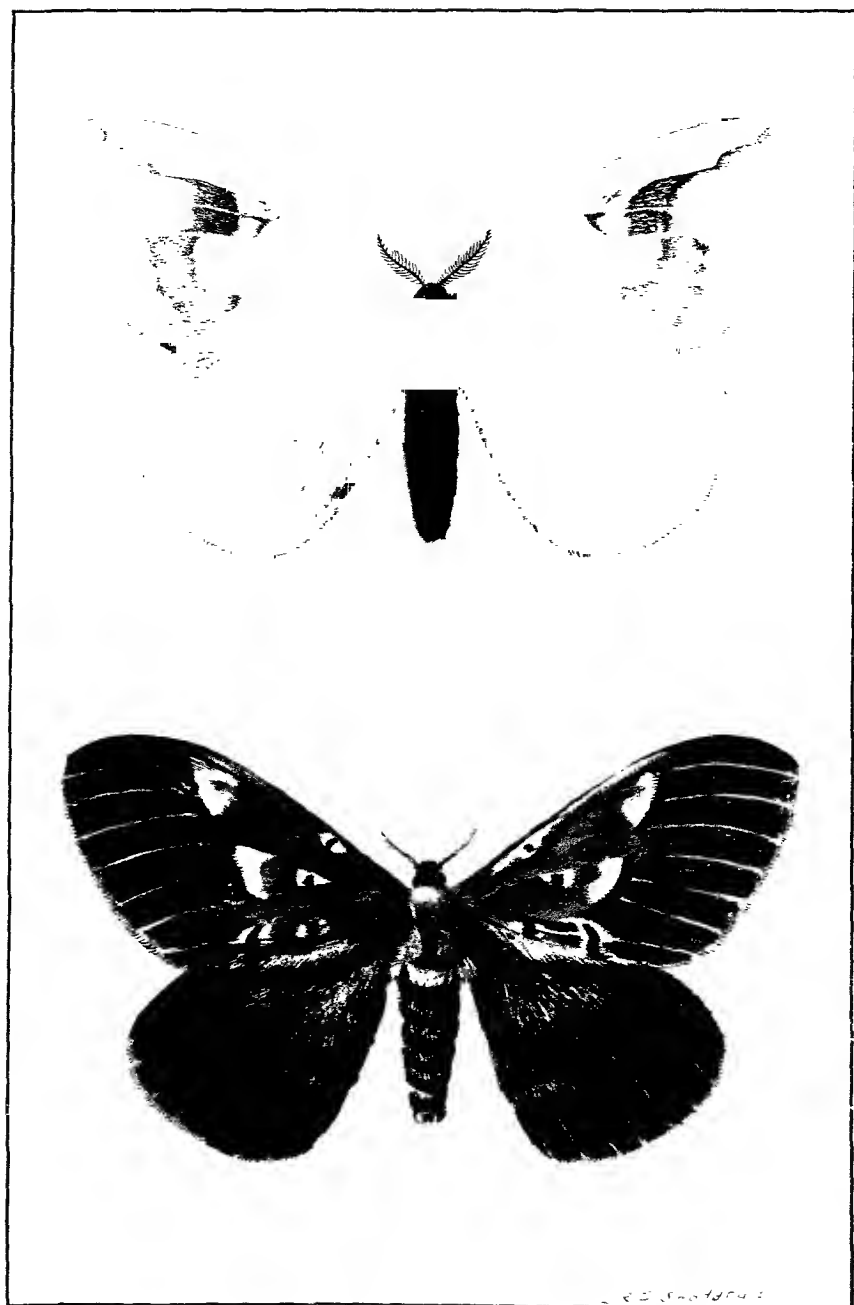




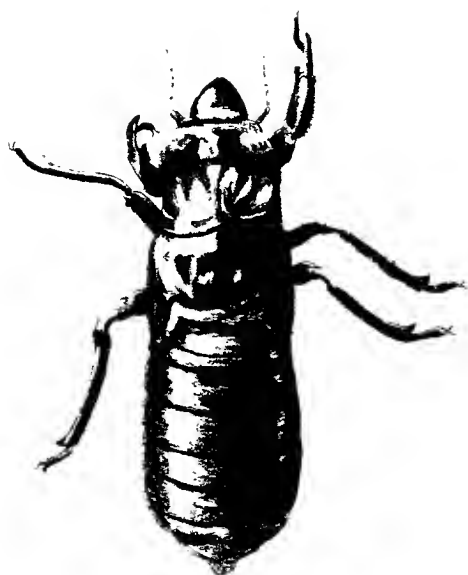




SEE "EXPLANATION OF PLATES."



SEE "EXPLANATION OF PLATES."



THE FULL-GROWN YOUNG CICADA, THE MATURE PUPA, AS IT EMERGES FROM
THE GROUND.

Colletes

THE SEVENTEEN-YEAR LOCUST.

By R. E. SNODGRASS.

Office of Deciduous Fruit Insect Investigations, Bureau of Entomology.

[With 5 plates.]

UNDERGROUND LIFE.

Most of our familiar insects are regulated in their changes by the seasons of a single year. Hence we marvel at the 17-year life of the periodical cicada, the insect generally known as the 17-year locust. Yet there are common insects that normally take two or three years to reach maturity, and certain beetles have been known to live for 20 years or more in the larval stage, though under conditions adverse for transforming to the adult form.

Still there is something about the cicada that stirs our imagination as no other insect does. For nearly 17 years it silently toils in dreary tunnels underground. Then a springtime comes when countless thousands of the creatures issue from the earth, undergo their startling transformations and swarm into the trees. Now the very air seems swayed with the monotonous rhythm of their song, while the business of mating and egg laying goes rapidly on till the twigs of trees and shrubs are everywhere scarred with slits and punctures where the eggs are placed. In a few weeks the swarm is gone, and we may not live to see their progeny return.

Different insects undergo various degrees of change as they progress from youth to maturity. Some, like the grasshoppers, change comparatively little; others, such as the moths and butterflies, go through three utterly dissimilar forms. The cicada is intermediate between these extremes. Its young is a tough-skinned creature (pl. 1) having the front feet specially formed for digging, but otherwise, aside from lacking wings and external organs for reproduction and egg laying, it is not radically different from its parents. It feeds, by means of a piercing and sucking beak, on the sap of the roots amongst which it burrows, in the same manner as the adult feeds on the sap in the twigs and branches of the trees amongst which it spends its life.

Of the underground life of the young cicada we still know very little. The fullest account of its history is that given by Dr. C. L.

Marlatt in his report, "The Periodical Cicada," Bulletin 71, United States Bureau of Entomology, published in 1907. Doctor Marlatt describes six immature stages between the egg and the adult, the first four of which are distinguished as larval stages and the last two as pupal. But this does not mean that the "pupa" of the cicada is a resting stage like that of the moth or butterfly. The cicada pupa (pl. 1) is an active creature like the larva (fig. 9), differing principally in having short wing pads. The first pupal stage begins in about the twelfth year of the insect's life.

In the spring of their seventeenth year the cicadas burrow upward through the soil till they come to within a few inches of the surface. Recorded observations indicate that this migration takes place during the month of April. We know that the insects leave the earth during the latter part of May, so it seems that they must gather just below the surface and there await for several weeks the proper time for their emergence. Then, all of a sudden, as if at a given signal, the mass of them issues in swarms every evening for several days, and the ground is perforated with their exit holes.

It is with a feeling akin to awe that we witness for the first time vast numbers of these insects issuing from the earth. Then we realize that they have all been quietly living beneath our feet these many years where we gave no thought to them. Each exit hole now becomes a dividing point for us between knowledge and ignorance—the history of the insects after reaching the surface is so easy to read, that before so difficult. What secrets have they left behind in those narrow tunnels?

The original notes on which this paper is based were made during the season of 1919 at Somerset, Maryland, where, through the courtesy of Dr. E. F. Phillips, the writer had use of a room in the house of the Office of Apiculture, United States Bureau of Entomology. Dr. Phillips also entered into a part of the work, especially that of studying the burrows, and the emergence and transformation.

One evening it occurred to us that something might be learned simply by pouring a water solution of plaster of Paris into the burrows. Accordingly, we filled a few at first, but many swallowed up so much of the liquid that we became hopeful of a real discovery and eventually filled a score or so and allowed the plaster to set over night. The drawings on figure 1 show a part of the results revealed on the next and several subsequent days as we unearthed the hardened casts. Each represents the outline of a subterranean chamber in which the pupa had been concealed, waiting the proper time for its emergence. The longest chamber reached to a depth of 6 inches, the shortest are mere cups. All have a more or less distinct enlargement at the bottom, and most of them a swelling at the top just beneath the narrow neck, which represents the emergence hole. In all

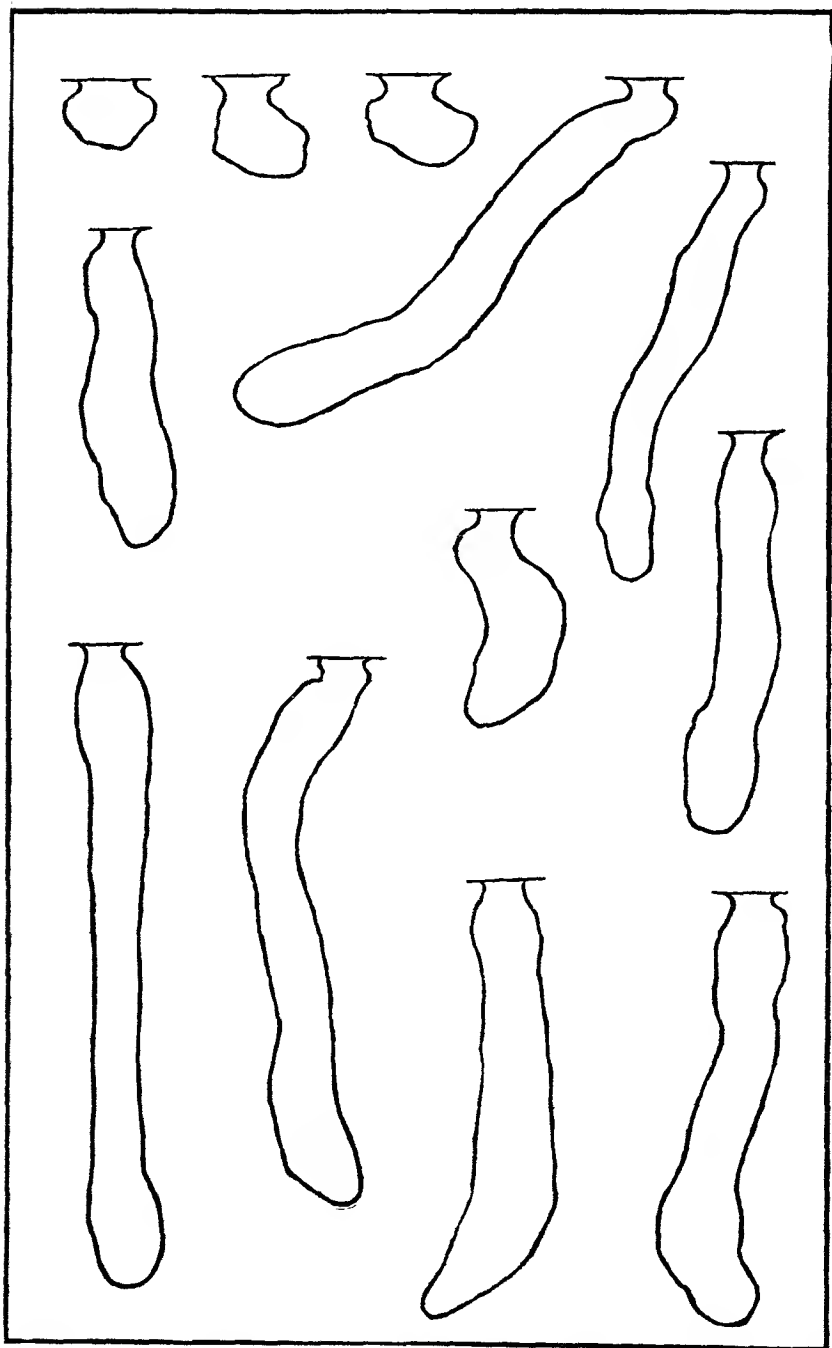


FIG. 1.—Outline of plaster casts from cicada pupal chambers in the ground (about one-half natural size).

but one the shaft has a diameter of about five-eighths of an inch, while that of the basal enlargement is seven-eighths of an inch. The neck averages about half an inch across. One cast is smaller, having the neck three-eighths of an inch in diameter, the shaft one-half, the lower swelling eleven-sixteenths. The individual that made this tube was most probably a pupa of the smaller form of the cicada, which will be described later in connection with the life of the adults.

The chambers are seldom straight, their courses being more or less tortuous and inclined to the surface, as the miner had to avoid roots and stones obstructing the path. The interior contains no débris of any sort, and the walls are smooth and compact. The largest chambers are many times the bulk of the pupa in volume, and the insect can easily turn around in them, though it can not quite sit cross-ways on the floor of the lower enlargement. Below the chamber there is always evidence of a narrower burrow going irregularly down into the ground, but this shaft is filled to the chamber floor with black granular earth. The burrows examined at Somerset were dug through compact red clay, so the filling of the lower tubes was probably discolored by the admixture of fecal matter. For this reason these tunnels always made a distinct black path through the red of the surrounding clay and could often be followed a considerable distance.

Before the emergence of the pupa the chambers are closed at the top by a cap of earth a quarter or a half inch in thickness, and this cap is the original earth surface. Where, then, is the material that was excavated in the construction of a hole of such size? Was it carried down into the tunnel beneath the lower rotunda? This tunnel is always much narrower than the diameter of the chamber and it would take a long section of its length to hold the excavations from the latter. Moreover, if the débris from the chamber was dumped into the hole below, what was done with the original contents of this cavity? Explaining one mystery by postulating another does not explain anything. As long as we have a hole to account for, we might as well account for the one we are sure of, and the best way to begin is by giving the insects themselves a chance to reveal their secrets.

Drop several pupae into glass tubes, fill the tubes with loose earth and watch the performance. Those pupae observed thus by the writer gave a very clear exhibition of their methods of work, which probably explains how they accomplish the seemingly impossible feat of digging a hole without throwing out any earth. They demonstrated first that they do not burrow by plowing through the earth with the conical nose-piece that caps their faces, though the earth in

the tubes was loose and might have been easily thus penetrated; nor did they claw their way along with the large front legs in any ordinary fashion. No; such is not the cicada's way; and what is not an insect's way it will not do even if it might. The cicada pupa has inherited different traditions in the art of digging. To understand its method of work we must first study the construction of its front legs, for these are its principal tools.

The front leg of the pupa is composed of the same number of parts as any other of its legs, as will be seen in figure 2 at *A*. The third joint from the base, called the femur (*F*), is large and swollen in the front leg, and has a pair of large spines and a comb of shorter ones projecting from its lower edge. The next joint is the tibia (*Tb*). It is curved and terminates in a strong hooked point. Finally, attached to the inner face of the tibia, well back from its distal end, is the slender foot or tarsus (*Tar*), which can be extended beyond the tibial hook when the insect is walking or climbing, but can also be turned in at right angles to the tibia, as shown at *B*, or bent back against its inner surface.

Let us now return to the insects laboring in the tubes. The use of the various implements on their front legs will be clearly shown. They are using the curved, sharp-pointed tibiae as picks with which to loosen the earth, the tarsi turned back and out of the way, the legs working alternately. When a small pile of loosened material accumulates a rake is necessary. This is furnished by the tarsus now turned inward at right angles to the tibia. A little pile is scraped back toward the body, and—here comes the important part, the cicada's specialty—the little pile of rakings is grasped between the tibia and the femur, the former closing up against the ventral spines of the latter, the leg strikes forcibly outward, and the fistful of loosened earth is mashed back into the surrounding earth. The process is repeated, first with one leg, then with the other. The digging cicada looks like a pugilist training on a punching bag. Now and then the worker stops and rubs its legs over the front of its head to clean them on the rows of bristles which cover each side of the face. Then it proceeds again, clawing, raking, gathering up the loosened particles, thrusting them back into the earth wall. Its

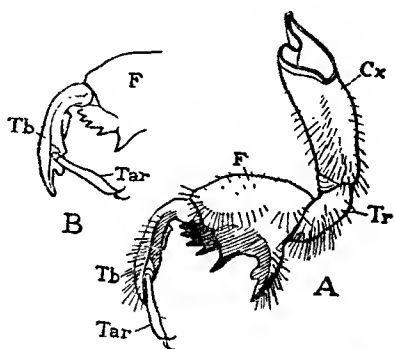


FIG. 2.—*A*, right front leg of mature pupa, inner side (4 times natural size); *Cx*, basal joint or coxa; *Tr*, trochanter; *F*, femur; *Tb*, tibia; *Tar*, tarsus, with two terminal claws. *B*, Showing the tarsus (*Tar*) bent inward at right angles to the tibia (*Tb*), the position in which it is used as a rake.

back is firmly pressed against the opposite side of the growing cavity, the middle femora are bent forward till their knees are almost against the bases of the front legs, their tibiae lying along the wing pads. The hind legs assume a normal position, though held close against the sides of the body.

Thus, the secret is out, the cicada excavates a closed cavity by crowding the earth back into the surrounding earth. What a slow and laborious task the construction of one of the larger chambers must be to the insect working within! Imagine a person making a cave of proportional dimensions in such a manner. No records are at hand to show when the cicada begins its work or how long it takes to finish the task. Those that performed in the tubes never emerged. But they had already left their original chambers and their time was ripe for transformation. Their skins split in the midst of their labors.

From what we know of the cicada's spring habits underground, we can infer that the pupae construct their chambers on their arrival near the surface during April. that, when the chambers are completed, the insects await within for the signal that it is time to emerge and transform into the adult. Then they break through the thin caps at the surface and come out. It would be difficult to explain how they know when they are so near the top of the ground, and why some construct ample chambers several inches deep, while others make mere cells scarcely larger than their bodies. Do they burrow upward till the pressure tells them that the surface is only a quarter of an inch or so away, and then widen the débris-filled tunnel downward? Evidently not, because the chamber walls are made of clean, compacted clay in which there is no admixture of the blackened contents of the burrows. It is unlikely, too, that they base their judgments on a sense of temperature, because their acts are not regulated by the nature of the season, which, if early or late, would fool them in their calculations. But time is only wasted in trying to reason out the acts of any insect. The insect is almost sure to have ways of its own that our reason seldom hits upon.

An interesting feature in the development, described by Doctor Marlatt, is the change that takes place in the size of the front feet. The young larvae, which hatch from the eggs in the trees, have well developed front tarsi. (Fig. 9.) In the succeeding three larval stages each front tarsus is reduced to a mere spur on the inner face of the tibia. Finally, in the pupal stages, the tarsi reappear as well-developed feet. Both the larva in the first stage and the pupa in the last stage spend a part of their lives on the trees, and to them the front tarsal claws are important climbing instruments; but in its other stages the creature lives entirely underground, where it digs

with the claw-like tips of the front tibiae. Thus the change in the feet is significant in connection with the change in habits, though, as has been shown, the long tarsi of the mature pupa play an important part in its digging also.

Early in the spring, before the proper emergence season, pupae are often found beneath logs and stones. This is to be expected—to the ascending pupae the surface is at the top of the log or the top of the stone. As they burrow upward something impenetrable blocks their paths, and that is all. But a more curious thing often observed is that, in some localities, the insects continue their chambers up above the surface of the ground within closed turrets of mud several inches high. Where these towers occur it is likely that there is something about the nature of the soil that the insects do not like; perhaps it is wet and the normal chambers are damp and moldy or partly filled with water. The writer had no opportunity to study the turrets since none were to be found at Somerset. The most interesting description of them is that given by Dr. J. A. Lintner in his Twelfth Report on the Insects of New York, published in 1897. Doctor Lintner states that "The chambers are constructed by the pupae with soft pellets of clay or mud brought up from below and pressed firmly into place," and he records that Mr. I. H. Lawton caught a pupa at work with a pellet of mud in its claws. Hence, we may infer that, as a mason, the cicada's style of work is only a modification of its working methods as a miner. Yet what an interesting sight it would be to watch the actual building of one of these adobe huts. At emergence time the towers are opened at the top and the insect comes forth as it would from an ordinary chamber opening at the level of the ground.

TRANSFORMATION.

By some feeling of impending change the pupa, waiting in its chamber, knows when the time of transformation is at hand. Somehow nature regulates the event so that it will happen in the evening, but once the hour has come no time is to be lost. The pupa must break out of its cell, find a suitable molting site and one in accord with the traditions of its race, and there fix itself by a firm grip of the tarsal claws. At the beginning of the principal emergence period, about the 21st of May, large numbers of the insects came out of their chambers as early as 6 o'clock by "daylight-saving time," which would be 5 o'clock by standard time; but after the rush of the first few days not many appeared before dusk.

It is difficult to catch a pupa in the very act of making its exit from the ground, and apparently no observations have been recorded on the manner of its leaving. At Somerset, in spite of closest scrutiny

and long vigils with electric light and lanterns, we were never lucky enough to witness an emergence. Other watchers at Falls Church, Virginia, report no better success. Do the insects leisurely open their doors some time in advance of their actual need and wait below till the proper hour, or do they break through the thin caps of earth and emerge at once? Digging up many open chambers revealed a living pupa in only one. Another issued from one of several dozen holes filled with liquid plaster for obtaining casts. Add to this the fact that great numbers of fresh holes are to be seen every morning during the emergence season, and the evidence would appear to indicate that the insects open their doors in the evening and come out at once. Only one chamber was found in the daytime partly opened.

If the insects are elusive and wary of being spied upon as they make their *début* into the upper world, a witness of their subsequent behavior does not embarrass them at all. However, events are imminent, there is no time to waste. The crawling insects head for any upright object within their range of vision—a tree is the ideal goal if it can be attained, and since the creatures were born in trees there is likely to be one near by. Yet it frequently happens that trees in which many were hatched have been since cut down, in which case the returning pilgrims must make a longer journey perhaps than they anticipated. But the transformation can not be delayed; if a tree is not accessible, a bush or a weed, a post, a telegraph pole, or a blade of grass will do. On the trees some get only so far as the trunk, others attain the branches, but the mob gets out upon the leaves. Though thousands emerge almost simultaneously, they have not all been timed alike. Some have but a few minutes to spare, others can travel about for an hour or so before anything happens. Several that I buried in the ground hoping to watch them emerge, transformed in their graves.

The external phase of transformation, more strictly the shedding of the pupal skin, has been many times observed. It is nothing more than what all insects do. But the cicada is notorious because it does the thing in such a spectacular way, almost courting publicity where most insects are shy and retiring. As a consequence the cicada is famous; the others are known only to prying entomologists.

Let us suppose now that our crawling pupa has reached a place that suits it, say on the trunk of a tree, or better still on a piece of branch provided for it in a lighted room where its doings can be more clearly observed. Though the insects choose the evenings for emergence, they are not bashful at all about changing their clothes in the glare of artificial light. The progress of this performance is illustrated by figure 3. The first drawing shows the pupa still creeping upward; but in the next (2) it has come to rest and is cleaning

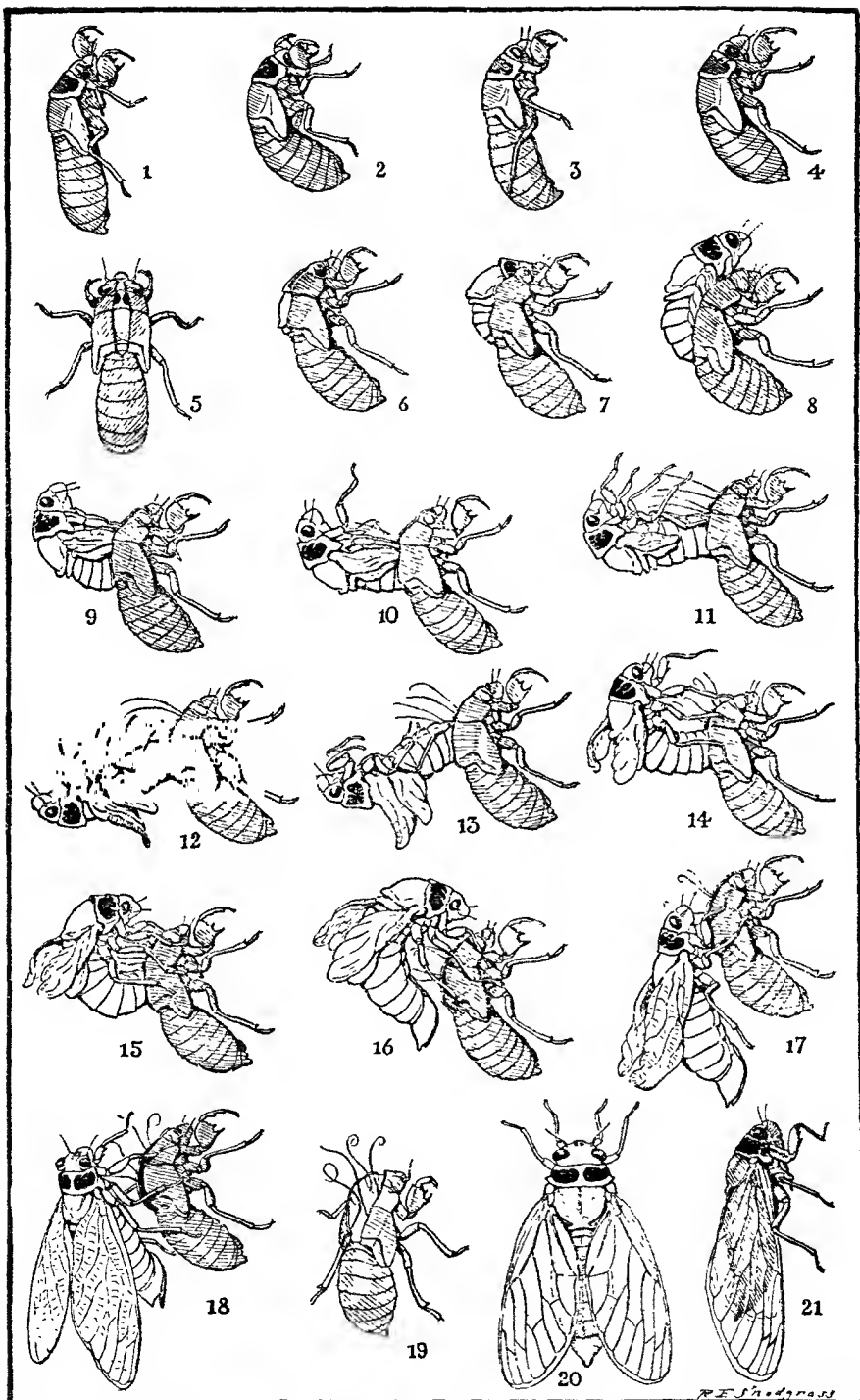


FIG. 3.—Transformation of the cicada from the pupa to the adult. At 1 the pupa is crawling upward. At 2 and 3 the feet are being cleaned against the head and body. At 4 the pupa assumes the molting position. At 5 the skin splits. From 6 to 15 the adult emerges from the pupal skin, becoming free at 16. At 20 it has left the pupal skin (19) and finally assumes the mature form at 21.

its front feet and claws on the curry combs of its face, just as did those confined to the glass tubes to give a demonstration of their digging methods. The front feet done, the hind ones are next attended to. First one and then the other is slowly flexed and then straightened backward (3) while the foot scrapes over the side of the abdomen. Several times these acts are repeated calmly and deliberately, for it is an important thing that the claws be well freed from any particles of dry earth that might impair their grip on the support. At last the toilet is completed, though the middle feet are always neglected, and the pupa feels about on the twig, grasping now here, now there, till its claws take a firm hold on the bark. At the same time it sways the body gently from side to side as if trying to settle comfortably for the next act.

Thirty-five minutes were consumed in the above preliminaries and there is now a 10-minute interval of quietude before the real show begins. Then suddenly the pupa humps its back (4), the skin splits along the mid line of the thorax (5), the rupture extending forward over the top of the head and rearward into the first segment of the abdomen. A creamy white back, stamped with two large jet black spots, now bulges out (6, 7); next comes a head with two brilliant red eyes (8); this is followed by the front part of a body (9), which bends backward and pulls out legs and bases of wings. Soon one leg is free (10), then four legs (11), while four long, glistening white threads pull out of the body of the issuing creature, but remain attached to the empty shell. These are the linings of the thoracic air tubes being shed with the pupal skin. Now the body hangs back down, when all the legs come free (12), and now it sags perilously (13) as the wings begin to expand and visibly lengthen.

Here another rest intervenes; perhaps 25 minutes may elapse, while the soft new creature, like an inverted gargoyle supported only by the rear end of its body, hangs motionless far out from the split in the back of the shell. Now we understand why the pupa took such pains to get a firm anchorage, for should the dead claws give way at this critical stage the resulting fall most probably would prove fatal.

The next act begins abruptly. The gargoyle moves again, bends its body upward (14), grasps the head and shoulders of the slough (15), and pulls the rear parts of its body free from the gaping skin (16). The body straightens and hangs downward (17). At last we behold the free imago, not yet mature but rapidly assuming the characters of an adult cicada. The new creature hangs for a while from the discarded shell-like pupal skin, clinging by the front and middle legs, sometimes by the first alone, the hind ones spread out sideways or bent against the body, rarely grasping the skin. The wings continue to unfold and lengthen, finally hang flat, fully formed, but soft



THE CICADA JUST AFTER EMERGING FROM THE PUPA. SKIN.
(Twice natural size)

and white (18). Here the creature usually becomes restless, leaves the empty skin (19), and takes up a new position several inches away (20).

At this stage the cicada is strangely beautiful. Its creamy-yellow paleness, intensified by the great black patches just behind the head and relieved by the pearly flesh tint of the mesothoracic shield, its shining red eyes, and the milky, semitransparent wings with deep chrome on their bases, make a unique impression on the mind. There is a look of unreality about the thing, which, out of doors (pl. 2), becomes a ghostlike vision against the night. But, even as we watch, the color changes, the unearthly paleness is suffused with bluish gray, which deepens to blackish gray. The wings flutter, fold against the back, and the spell is broken—an insect sits in the place of the vanished specter.

The rest is commonplace. The colors deepen, the grays become blackish and then black, and after a few hours the creature has all the characters of a fully matured cicada. Early the next morning it is fluttering about, restless to be off with its mates to the woods.

The time consumed by the entire performance, from the splitting of the skin (fig. 3, 5) to the folding of the wings above the back (21), varied with different individuals, observed at the same time and under the same conditions, from 45 minutes to 1 hour and 12 minutes. Most of the insects had issued from the pupal skins before 11 o'clock at night, but occasionally a straggler might be seen in the last act as late as 9 o'clock the following morning. Such were probably belated arrivals who overslept the night before.

Thus, to the eye, the burrowing and crawling creature of the earth becomes transfigured to a creature of the air; yet the visible change is mostly but the final escape of the mature insect from the skin of its preceding stage. Aside from a few last adjustments and the expansion of the wings, the real change had been in progress within the pupal skin perhaps for years. We do not truly witness the transformation; we see only the throwing off of the shell that concealed it, as the circus performer strips off the costume of the clown and appears already dressed in that of the accomplished acrobat.

THE ADULTS.

The adult cicada bears the stamp of individuality; he does not closely resemble any of our everyday insects; he has a different personality: he impresses us as a "distinguished foreigner in our midst." Of course, he has near relations: there are numerous other members of his family, the insects commonly called "locusts," whose shrill voices are more familiar to us than their faces, but whose empty pupal skins almost everyone has seen adhering to fence posts and

tree trunks in late summer. Most of these cicadas probably go through their underground changes in one year, but there are periodical species whose lives we as yet know nothing about.

The 17-year cicada has a thick-set body (fig. 4), the forehead is wide, with the eyes set out very prominently on each side. He is distinctively but not strikingly colored. The back is plain black (pl. 3); the eyes bright red; the wings shiny, transparent amber with strongly marked orange-red veins; the legs and beak are reddish and there are bands of the same color on the ventral rings of the abdomen. Each front wing is branded with a conspicuous brown W toward the tip. Superstition, of course, must explain this only as meaning "war," but the 1919 brood evidently miscalculated what

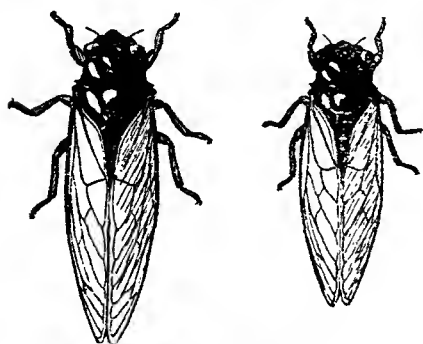


FIG. 4.—Males of the large and the small form of the cicada (natural size).

was going on above ground.

The male cicada is noted for his "song," yet his music is of an instrumental order rather than vocal. He carries a pair of large drumheads beneath the bases of his wings, the ridged, parchment-like surfaces of which are thrown into rapid vibration by a pair of pillarlike muscles in the front part of the abdomen (fig. 7, *Tm.Mcl*). Below the drums, between the thoracic and abdominal

divisions of the body on each side, is a large cavity with tense membranes on its walls, which most probably act as resonators. The cavities are closed below by a pair of large flaps projecting back from the thorax, but they can be opened by the elevation of the abdomen.

The female has no drums, and consequently is doomed to keep silence; but no one has yet discovered that she possesses ears, so it seems she also does not have to listen to her noisy mates. Her chief distinction is her ovipositor, a swordlike instrument used for inserting her eggs into the twigs of trees and bushes. Ordinarily it is kept in a sheath beneath the rear half of the abdomen, but when used (pl. 3) can be turned forward by a hinge at its base. The ovipositor consists of two lateral blades and a guide rail above. The blades excavate the egg nests in the wood and then the eggs are passed into the nests through the space between the blades.

Entomologists call the 17-year cicada *Tibicena septendecim*. But there are two forms (fig. 4), distinguished by their size and by their song. The smaller form has been given the name *Tibicena cassini* or *Tibicena septendecim cassini*, according to whether it is regarded



FEMALE CICADA DEPOSITING EGGS IN APPLE TWIG.

(Twice natural size.)



as a distinct species or only as a variety of the larger form. The two kinds occur together, but they are not known to intermarry; they occasionally intergrade in size, and no constant physical differences have so far been found between them.

It was formerly supposed that the cicadas take no food during the brief time of their adult life, but we now know, from the observations of Mr. W. T. Davis, Dr. A. L. Quaintance, and others, and from a study of the stomach contents recorded in this paper, that they do feed abundantly by sucking the sap from the trees and bushes on which they live. The cicada is a large relation of the aphids, the scales, and other insects of the sucking order, and like them has a beak for piercing the plant tissues and drawing the sap up to its mouth. But, unlike the aphids and scales, the cicadas seldom cause any visible damage to the plants by their feeding. Perhaps this is because their attacks last such a short length of time and come at a season when the trees are at their fullest vigor.

The details of the head structure and the exposed parts of the beak are shown in figure 5, A, which is a side view drawn from the head of a fully matured adult, detached from the body by the torn neck membrane (*mb*) with the long slender beak (*Lb*) projecting below. The cicada has no jaws. Its mouth is shut in between a large front lip (*Clp*), and the base of the main part of the beak (*Lb*), which is really the prolonged lower lip, or labium. The narrow spaces on the sides between the bases of the lips are closed by the soft, slender pieces marked *Lm* and *c*.

If these outer parts can be separated, we find some other very important parts hidden from view within them. But it is difficult to separate them on the hardened head of a fully matured specimen. However, if we take an insect in the act of emerging from its pupal skin, when it is still soft, the parts are easily spread out, exposing all the structures shown in figure 5, B. In the front half of the space between the lips (*Clp* and *Lb*) there is exposed a large tongue (*Hphy*), the hypopharynx, which is connected by a flaring wing (*a*) on each side with the first side plate (*A*) of the head. Between this tongue and the front lip (*Clp*) is an open cleft (*Mth*) which is the cicada's mouth. It opens into the pharynx, whose roof (*e*) bulges in and almost fills its cavity. The lobe (*b*) behind the tongue is the same thing as *b* on figure A, being merely a downward extension of the second side plate (*B*) of the head, and carries the soft appendage (*c*), already noted, at its lower end. Between this lobe (*b*) and its mate on the opposite side of the head are two deep pouches, from each of which there issues a pair of long, slender, bristlelike rods (*1 Set* and *2 Set*), which are called the setae. (Only the left pair is shown in the drawing.)

Now, if these separated parts be put together again we get a pretty clear idea of how the cicada takes its food. The setae (*1 Set* and *2 Set*), normally lie deep in a groove along the front side of the labium (*Lb*), which groove, of course, does not show in the drawing made from the side. The upper ends of the setae have arms extending into the head cavity which have two sets of muscles attached to them—

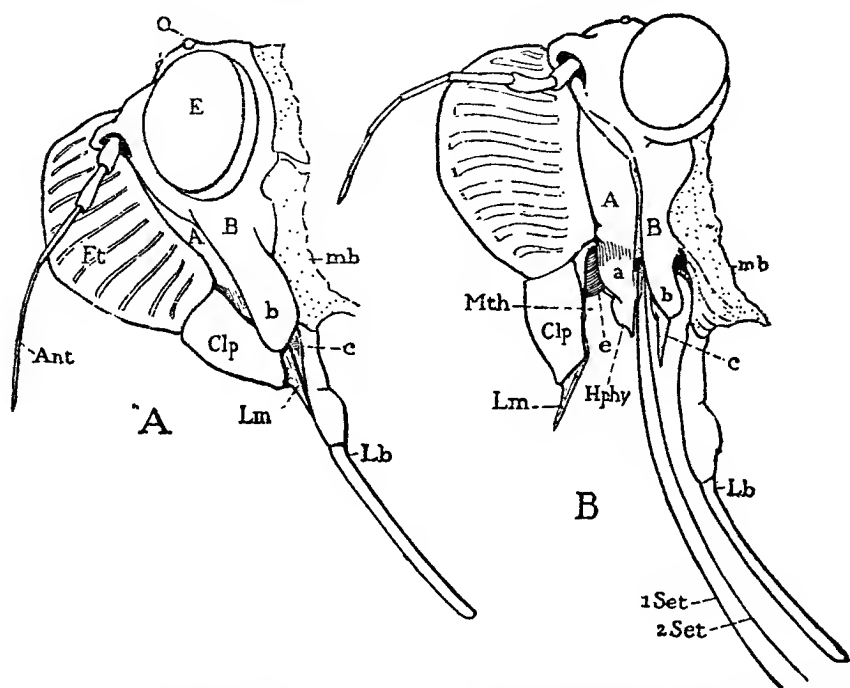


FIG. 5.—Showing the anatomy of the head of an adult cicada (7 times natural size). A, First side plate of head; *a*, attachment of hypopharynx to the head; *Ant*, antenna; B, second side plate of head; *b*, lower lobe of B; *c*, appendage of *b*; *Clp*, clypeus; E, compound eye; *e*, roof of the pharynx; *Ft*, front; *Hphy*, hypopharynx; *Lb*, labium; *Lm*, labrum; *mb*, neck membrane; *Mth*, mouth; *O*, simple eyes or ocelli; *1 Set*, first seta; *2 Set*, second seta. A, The mature head with the parts in natural position. B, Soft head of a transforming adult with the parts separated, showing the month (*Mth*) wide open, the tongue or hypopharynx (*Hphy*) suspended behind it, and behind the tongue the setae (*Set*) inserted into pouches of the head. Only the left setae are shown. In the normal head (A) they are concealed in a groove on the front side of the labium (*Lb*).

the fibers of one set, going up to the top of the cranium, draw the setae up by contraction; those of the other, coming down and sideways from the tops of the arms to the inner faces of the head plates A and B, push the setae out when they contract. Thus, by these muscles, the tips of the setae can be worked in and out at the end of the beak and made to pierce the bark of the tree. As they enter, the labium (*Lb*), which incloses them like a sheath, can be drawn up into the flexible membrane (*mb*) at its base, so that the setae can be

pushed a long distance down into the sap-carrying tissues of the tree. Next the sap must be drawn up to the mouth. To serve this function two of the setae, the rear one of each lateral pair, are hollowed along their inner faces and united lengthwise by interlocking grooves and ridges. Thus a closed channel is formed between them, and it is through this tube that the sap reaches the mouth, going up probably by the mechanical force that makes all liquids flow up through hairlike tubes.

The immature adult cicada has the mouth open, or easily opened; but when fully matured the mouth is always tightly closed by the tongue (*Hphy*) and its wings (*a*) which press firmly against the roof of the mouth. The middle part of the tongue then fits snugly into a depression of the palate or epipharynx, as the roof of the mouth is called in insects. Hence, there would be no mouth opening at all if it were not for a small median groove on the front surface of the tongue. This groove is now converted into a tube which opens below at the pointed tip of the tongue, and above into the cavity of the pharynx. The pair of united setae carry the liquid food up to the mouth, but, right at the point of the tongue, they flare apart and embrace the tongue tip. This allows the liquid stream between them to pass on without interruption into the mouth pore through which it is sucked up into the pharynx. The sucking apparatus consists of the collapsed roof of the pharynx (*e*) which can be elevated by a

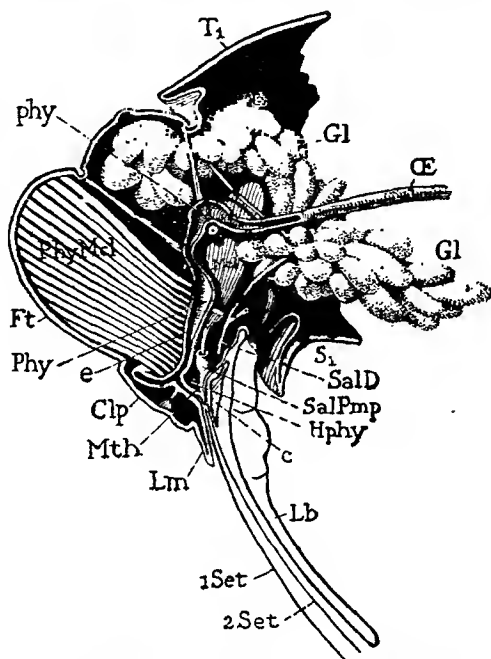


FIG. 6.—Median vertical section through head of an adult cicada showing the sucking pharynx (*Phy*) and the salivary glands (*Gl*, *Gl*). The liquid food goes up to the mouth between the second setae (*2 Set*), all being normally enclosed in the groove of the labium (*Lb*). The pharynx muscles (*PhyMcl*) contract and pull out the front wall (*e*) of the pharynx, thus sucking in the liquid from between the bases of the setae through the mouth pore (*Mth*). When the muscles relax the pharynx wall (*e*) collapses again and forces the liquid up into the bulb (*phy*) from which it goes into the gullet (*œ*). The salivary duct (*SalD*) opens at the tip of the hypopharynx (*Hphy*), the saliva being forced out by the salivary pump (*SalPmp*). *Ft*, *Clp* and *Lm* are the front, clypeus and labrum shown on figure 5, while *c* is the appendage of head plate *B*. *T₁* and *S₁* are the dorsal and ventral plates of the first thoracic segment.

special set of large muscles attached to the front of the head. A sectional view of it is shown by figure 6.

Insects that devour the leaves or any kind of solid food, as do grasshoppers, beetles and caterpillars, have a pair of large strong jaws for biting and chewing and a second pair of softer jaws with movable appendages that serve a variety of purposes accessory to the first pair. Since the cicada and its relations, constituting the order of insects called Hemiptera, have no jaws like those of the biting insects, it has usually been assumed that the pair of setae on each side are their representatives and this appears to be confirmed by a study of their development.

SONG.

During the first two weeks of June the woods were full of the "locusts" and the noise of their singing. The song has no resemblance whatever to the shrill, undulating screech of the annual locusts so common in August and September and known as the dog-day cicadas. The song and all the notes of the larger variety of the 17-year cicada are characterized by a burr sound and at least four different utterances may be distinguished. First, there is the prolonged burring sound of their ordinary song, the individual notes of which become lost in the continuous hum of the multitude, and I never heard one singing this song in solo. Next there is the so-called "Pharaoh" note, which requires some imagination to interpret it thus, for it is characterized by the same burr tone as the chorus song. The Pharaoh sound is usually sustained only about five seconds, when it terminates with an abrupt falling. Then it is repeated indefinitely at intervals of two to five seconds. When each note is begun the singer lifts his abdomen to a rigid, horizontal position, evidently thus opening the ventral drum chambers. As the sound ends the abdomen drops again to the usual somewhat sagging position, seemingly thus cutting off the sound by closing the drums; but, of course, the two are coincidental, since the sound terminates when the tympanal muscles cease to vibrate.

The males are easily observed uttering the Pharaoh song as they sit in the bushes or on low branches of the trees, but the community singing is always done in the tops of the trees, where I never observed an individual musician at close range while performing.

Their third note is a soft purring sound of one syllable, which is often heard from those sitting low in the bushes. It is shorter than the Pharaoh sound and lacks the abrupt terminal drop. Finally, when a male appears to be surprised or frightened, he often, as he darts away, utters a loud, rough burr sound. They utter the same note when picked up or otherwise handled. This seems to be their

note of "primitive passion," and if so is perhaps the one from which the more melodious ones have been developed.

The smaller form, variety, or species, the one called "cassini," differs from the larger form in the character of its notes always, if in no other way. The regular song of the little males much more resembles that of the annual summer cicadas, though not so long and less continuous in tone. It commences with a few chirps, then there follows a series of strong, shrill sounds like *zwing, zwing, zwing*, etc., ending again in a number of chirps. The whole song lasts about 15 seconds. Several of these males kept in jars sang this song repeatedly and sang no other. It was common out of doors, but always heard as a solo, never in chorus.

When handled or disturbed the little males utter a series of sharp chirping notes very suggestive of a miniature wren angrily scolding at an intruder. Never does this form utter notes having the burr tone of the larger one. The contrast between the vocal tones of the two is strikingly evident when several males of both kinds are kept together in a jar. If disturbed each produces his own sound, one the burr, the other the chirp, and there is never any suggestion of similarity or gradation between them.

Of all animal songs, the song of the cicada must prove one of the worst stumbling blocks to those who would explain animal music on the theory of sexual selection. Where thousands of males are singing all at once it would be a very delicate ear that the female must have to choose amongst them: and, furthermore, as has already been mentioned, the female is not known to have any ear at all. On the other hand, probably no one is able to give any very satisfactory reason why an insect should have acquired such an elaborate music box as that of the cicada's merely for the purpose of emotional expression.

EGG LAYING.

The cicadas lay their eggs in the twigs of trees and shrubs and frequently in the stalks of deciduous plants. They show no particular choice of species except that conifers are usually avoided, though Mr. W. T. Davis says that he has observed them ovipositing in pines on Staten Island, but he did not examine the eggs later to determine whether they hatched or not.

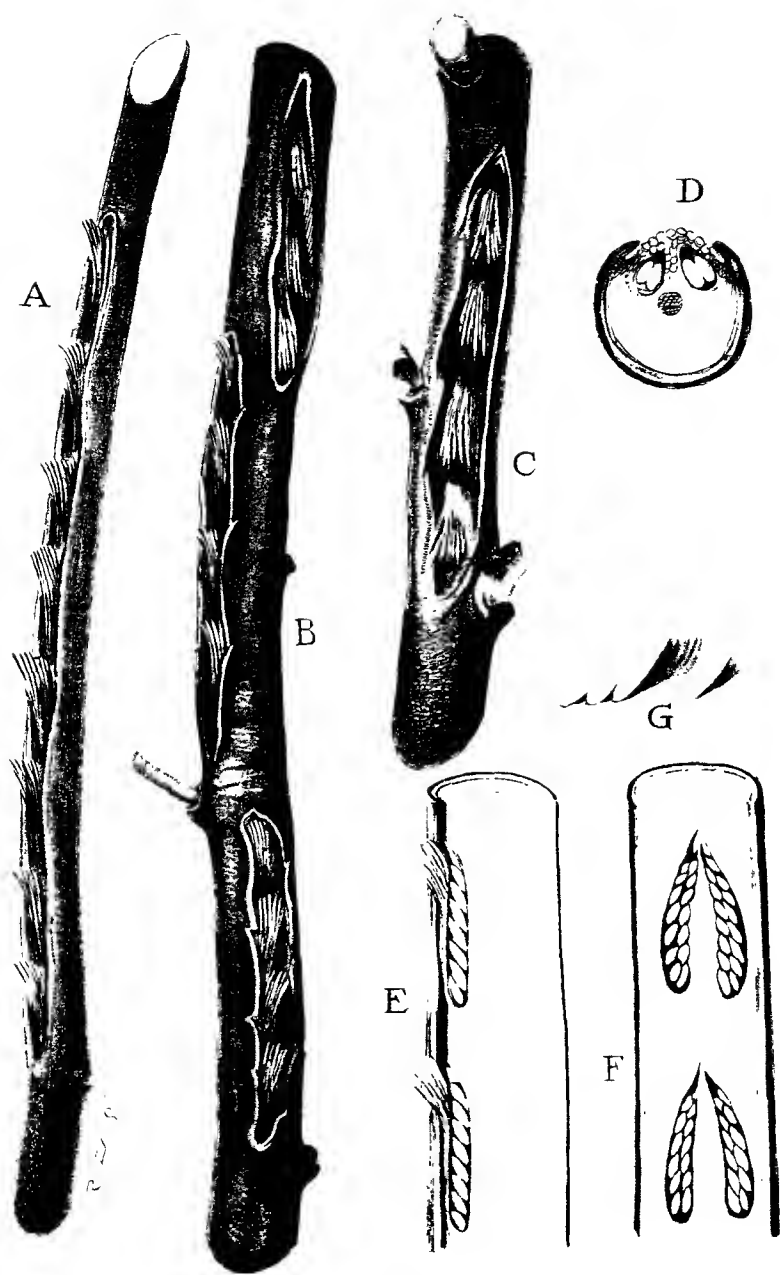
The eggs are not stuck into the wood at random, but are carefully placed in skillfully constructed nests which the female excavates in the twigs with the blades of her long, curved ovipositor. (Pl. 3.) These nests are perhaps always on the undersurfaces of the twigs, unless the later are vertical, and usually there are rows of from half a dozen to twenty or more of them together.

Egg laying begins in the early part of June. The first evidence the writer noticed in 1919 was on June 6, when a number of punctured twigs were found on several varieties of trees and shrubs at Chevy Chase Circle, but no particular search was made for them earlier than this date. By June 10 egg laying was at its height. The females could easily be watched at work, taking flight only from actual interference. They usually select twigs of last year's growth, but often use older ones or green ones of the same season. In the majority of cases the female works outward on the twig; but if this is a rule, it is a very loosely observed one, for many work in the opposite direction.

Each nest is double; that is, it consists of two chambers having a common exit, but separated by a thin vertical partition of wood (pl. 4, *D* and *F*). The eggs are placed on end in the chambers in two rows, with their head ends downward and slanted toward the door. Generally there are 6 or 7 eggs in each row (*E*), making 24 to 28 eggs in the whole nest, but frequently there are more than this. The wood fibers at the entrance are very much frayed out by the action of the ovipositor and make a sort of fan-shaped platform in front of the door, where the young shed their hatching garments on emerging from the nest. The series of cuts in the bark eventually runs together into a continuous slit, the edges of which shrink back so that the row of nests comes to have the appearance of being made in a long groove (*A*, *B*, *C*). This mutilation kills many twigs, especially those of oaks and hickories, the former soon showing the attacks of the insects by the dying of the leaves. The landscape of oak-covered regions thus becomes spotted all over with red-brown patches which often almost cover individual trees from top to bottom. Other trees are not so much injured directly, but the weakened twigs often break in the wind and then hang down and die.

An ovipositing female finishes each egg nest in about 25 minutes; that is, she digs it out and fills it with eggs in this length of time, for each chamber is filled as it is excavated. A female about to oviposit alights on a twig, moves around to the undersurface, and selects a place that suits her. Then elevating the abdomen, she turns her ovipositor forward out of its sheath and directs its tip perpendicularly against the bark. As the point enters it goes backward, and when in at full length the shaft slants at an angle of about 45°.

The following detailed observations were made on a female who had already finished several nests of a series. In beginning the new nest she first made three partial insertions of the ovipositor, drawing it out entirely after each slow penetration. At the end of the first five minutes she finally worked it in to its full length. Then, during five minutes more, it was pulled out and worked in again



A, B, C, twigs of dogwood, oak, and apple containing rows of cicada egg nests; D, cross section of twig through an egg nest showing the two chambers, each containing a double row of eggs; E, vertical section through two egg nests showing the rows of slanting eggs and the frayed lip of the opening; F, horizontal section showing each chamber filled with double row of eggs.

a number of times. Finally the ovipositor was sunk so deep that the abdomen came up close against the bark and egg-laying began, as indicated by the regular contractions of the plates of the ninth abdominal segment that operate the ovipositor blades. At short intervals the instrument was drawn out nearly to the tip and then thrust in again, but each time not so deep as the time before. This stage lasted another 5 minutes, 15 minutes in all having elapsed since the start. Now the abdominal pulsations ceased and the ovipositor was again sunk full length into the wood; repeated probings occupied the next 7 minutes. This was followed by a second period of egg laying, lasting 3 minutes, while the thrusts became shorter and shorter. Finally, the ovipositor was withdrawn, snapped back into its sheath, and the female flew away. The whole operation had taken 25 minutes.

In a number of other cases the females were frightened away at different stages of their work, and an examination of these unfinished nests showed that each chamber is filled with eggs as soon as it is excavated; that is, the insect completes one chamber first and fills it with eggs, then the other chamber is dug out and in turn receives its quota of eggs, when the whole job is done. The female then moves forward a few steps and begins work on another nest, which is completed in the same fashion. Some series consist of only 3 or 4 nests, while others contain as many as 20 and a few even more, but perhaps 8 to 12 are the usual numbers. When the female has finished what she deems sufficient on one twig she flies away and is said to make further layings elsewhere, till she has disposed of her 400 to 600 eggs, but the writer made no observations covering this point. Probably the cicada feels it safer not to intrust all her eggs to one tree, on the principle of not putting all your money in the same bank.

DEATH.

From the time that egg laying was at its height, about the 10th of June, the din of the singing in the woods began to diminish. Many insects were from the first killed or mutilated by birds or small mammals; now the ground became strewn with dead bodies or with insects still living, but hopelessly injured and dismembered. By the 13th and 14th of the month the colony was reduced to a very miserable condition. Great numbers were dead or dying, and a large percentage of the living were walking around on the ground in various stages of disfigurement. Wings were torn off; abdomens were broken open or gone entirely; mere fragments crawled about, still alive if the head and thorax were intact. It was almost a gruesome sight to see these half creatures, the males often with the great muscle columns of the tympana exposed and visibly quivering.

Many, game to the end, even in their depleted condition still uttered purring remnants of their song.

On June 15 at Somerset I heard one solitary male singing, but by the 17th all was over; the great horde of insects that emerged from the earth and underwent such spectacular transformations only three or four weeks ago was gone. Mutilated remains and dried bodies could still be found, but a thorough search revealed not one living insect. On June 29 a belated male was heard near Riverdale, Maryland, faintly but distinctly singing the Pharaoh song, then he ceased and was heard no more.

From now on till the 24th of July there was no evidence of the late swarm of visitors except that of the scarred twigs on the trees and bushes and the red-brown patches of dying leaves that everywhere disfigured the oaks and hickories.

INTERNAL ANATOMY.

In observing those mutilated cicadas, with their abdomens wide open clear up to the thorax, it strikes one as remarkable that a bird could do such a neat job of evisceration on a living subject. It seems that an insect here and there should have a piece of intestine trailing behind or should retain at least some remnant of its vitals. But the vivisection is never messed by so much as a protruding shred, and the cavity is always as clean and bare as if it never had contained anything. One's curiosity is aroused to know what might have been there in the natural state. The live cicada looks like a plump catch for any predaceous creature. So the writer was led to investigate its abdominal anatomy, and eventually dissected many specimens to be sure there was no nature faking—each was as empty as a rubber ball, as empty as those walking shells that so arouse one's pity and curiosity. If I was surprised, one can imagine that the feelings of the birds were something worse—where they expected a juicy meal, they found only an empty dish!

After considerable study the facts were ascertained as follows: The abdomen is almost filled by a great air chamber (fig. 7) whose anterior end narrows between the pillars of the tympanal muscles and tapers to a point in the prothorax! The reproductive organs (*Rpr*) and the terminal part of the alimentary canal (*Rect*) are crowded into a small space in the rear part of the abdomen. Otherwise the walls of the chamber appear to form an inner lining against the hard abdominal rings, so closely are they applied to them. Yet this is not really the case. If the dissected specimen be placed in water, a transformation appears; a complicated intestinal tract swells up along the back; muscles, tracheæ, and nerves come into view, all packed about the outside of the thin, transparent walls of the air chamber.

The alimentary canal, when once its numerous tubes are disentangled, shows the remarkable arrangement depicted on plate 5.

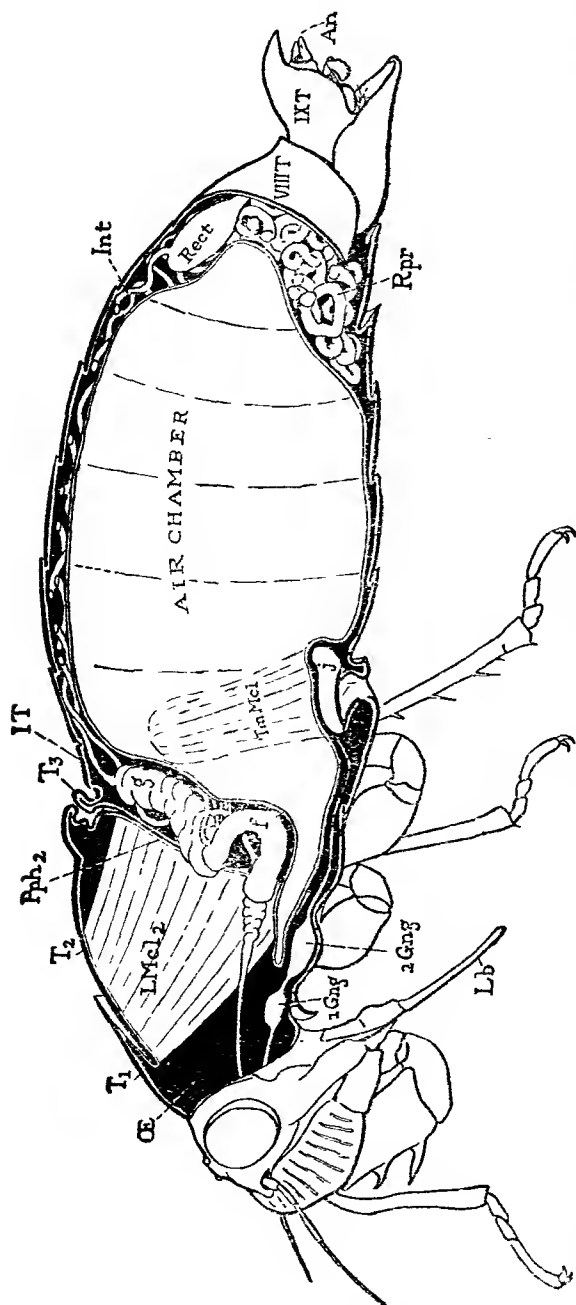


FIG. 7.—Vertical section of a male locust's body through the middle line, showing the large, empty, internal cavity formed by the great air chamber, with the viscera crowded into the narrow spaces around it. *An*, anus; *f*, *g*, the two compartments of the stomach; *IGang*, *IGang*, first and second nerve ganglia in the thorax; *Int*, intestine; *IT*, back plate of first abdominal segment; *IXT*, back plate of ninth abdominal segment; *j*, plate bearing attachment of the tympanal muscles (*TmMcl*); *Lb*, the beak (labium); *LMcl*, longitudinal muscles of middle thoracic segment; *OE*, oesophagus; *Rpr*, reproductive organs; *T₁*, *T₂*, *T₃*, back plates of the three thoracic segments; *TmMcl*, tympanal muscle of the right singing drum; *VIIIT*, back plate of the eighth abdominal segment.

The esophagus (*OE*) is a slender tube enlarging at its rear end into a distensible crop. The crop is followed by a long S-shaped stomach

of two compartments (*f* and *g*). Six tubes appear to leave the stomach. The first (*Int*) issues from the anterior end of the front stomach compartment and goes rearward in many crosswise loops along the back till finally it ends in the pear-shaped rectum (*Rect*), which opens to the exterior through the anus. This tube (*Int*) must, therefore, be the true intestine. From the rear end of the second stomach compartment, which is of an orange-brown color, there issues a tube (*h*) of the same color, which goes backward in many loops and folds but eventually turns forward again and penetrates the stomach at the constriction between its two compartments. On the same line there issue four very small whitish tubes (*i*) which form two loops inextricably tangled amongst the folds of the intestine.

At first sight this alimentary structure is a puzzle—the intestine issues from the front end of the stomach, while the tube arising from the rear end of the stomach, where the intestine should begin, turns back on itself and reenters the stomach. The explanation is simple, however, and is easily found by dissecting the first stomach compartment. The tube (*h*), entering the rear end of this compartment, does not open into the stomach cavity but merely penetrates between its muscular wall and its interior lining, where it goes forward in many zigzag loops and issues at the top as the tube *Int*. The tubes *i* arise from the enclosed end of the intestine (*Int*) in two pairs from two short basal tubes and go backward in the stomach wall from which they issue, as shown on the plate, at the front of the second stomach compartment. These are the Malpighian tubules which function as the kidneys in insects.

Thus the puzzle of the anatomy is solved, but we are not sure of any reason for such an unusual state of things. Some entomologists, however, have supposed that the arrangement affords a shortcut to the intestine for some of the waste matter in the stomach, which can soak through into the upper end of the tube *h* and thus go direct to the intestine (*Int*), while the nutritive material goes on by way of the long loop (*h*, *h*, *h*). They would, hence, name the first compartment of the stomach the "filter chamber." But it is not clear how the tubes can select waste matter in solution from nutritious matter in the same liquid.

Both the stomach and the sac of the rectum are usually filled, and frequently tensely distended, with a clear liquid. The presence of such an elaborate digestive system, with its retaining parts thus filled with liquid, only adds confirmation to the observed facts of the cicada's feeding already recorded. The two stomach sacs (*f* and *g*) lie in the narrow, almost vertical, space between the posterior phragma (fig. 7, *Pph₂*) and the anterior end of the air chamber. The tubular parts are packed into the flat space above the chamber, a



THE ALIMENTARY CANAL OF THE CICADA.

œ, the esophagus; *f, g*, the two compartments of the stomach; *h, h, h*, tubular continuation of the stomach entering the walls of the first compartment where it unites with the small intestine (*Int*), which issues from near the front end of the stomach and finally opens into the rectum (*Pecty*).

space no thicker than a piece of paper in those individuals examined toward the end of their natural lives. The rectum (*Rect*) lies in a freer space again behind the air chamber and above the reproductive organs (*Rpr*).

The great air chamber is a part of the respiratory system. It receives its supply of air directly through the spiracles of the first abdominal segment, which lie just before the drums in the male, as described by Vitus Graber in 1876. At least two tracheal tubes open from it on each side close to the spiracle, and its own walls are abundantly supplied with fine branching tracheae. It is present in the last pupal stage where it is to be found at the time of emergence as a collapsed bag with rather thick walls lying lengthwise amongst the abdominal viscera (or at least it is thus in alcoholic specimens). It is distended in the imago when the latter first comes out of the pupal shell, and is present in both males and females, enlarging toward the end of adult life as the reproductive organs shrink into the rear extremity of the abdomen. In the young female, before egg laying has exhausted the ovaries, these organs occupy a much larger space at the expense of the air sac than they do toward the end of life. If the air chamber occurred in the male alone it would easily be explained as part of his musical equipment. The dry, hollow, thin-walled abdomen would be enthusiastically described as a marvelous adaptation for giving resonance to the vibrations of the tympana. But the female contradicts this theory, unless it be that her body is set into sympathetic vibration by the song waves from the male. We shall probably have to fall back on the old prosaic explanation that bulk of body is maintained with corresponding weight eliminated—a combination specially favorable to aerial life.

In the narrow space about the sac there are, besides the alimentary canal, abundant strands of fat tissue, the heart, tracheal trunks from the spiracles and their numerous branches, nerves, and the muscles of the body wall. So, indeed, the cicada is a complete insect after all in spite of its deceptive appearance of emptiness.

The central nervous system consists of four main ganglia, the two usual ones in the head, one in the prothorax (fig. 7, 1 *Gng*), and a larger one in the mesothorax (2 *Gng*). This explains why the loss of the abdomen is a matter of such little consequence to these insects, and also why the cicada appears to be such a perfect automaton.

HATCHING.

Knowing from printed records that the cicada eggs were due to hatch almost any time after the middle of July, the infested trees in the yard of the Office of Apiculture were daily inspected from the 15th

on, but no evidence of hatching was found until the 24th. Egg laying had been at its height about the 10th of June, so fully seven weeks had elapsed already and no nymph had yet been seen. Possibly the normal hatching was retarded by the heavy rains that fell almost continuously during the 10 days previous. Many eggs examined were found dead and turning brown, but the percentage of such was small. On the 24th there was no rain and the sky was only partly cloudy. The usual search revealed two nymphs on a punctured twig of a small chinquapin, but that was all. Some of the nests examined showed a few empty shells, but, judging by their proportion, the great majority were still unhatched.

The next day, the 25th, was hot and bright all day. The trees were inspected in the afternoon. Their twigs had been bare the day before. Now, at the entrance holes of the egg nests were little heaps of shriveled skins, thousands in all, and each so light that the merest breath of air sufficed to blow it off; so, if according to this evidence thousands of nymphs had hatched and gone, the evidence of as many more must have been carried away by the winds. An examination of many egg nests themselves showed that over half contained nothing but empty shells. Whole series were thus deserted, and usually all or nearly all of the eggs in any one series of nests would be either hatched or unhatched. But often the eggs of one or more nests would be unhatched or mostly so in a series containing otherwise only empty shells. Delay appeared to go by nests rather than by individual eggs.

As a very general rule the eggs nearest the door of an egg chamber are the ones that hatch first, the others following in succession, though not in absolute order. But unhatched eggs, if present, were always found at the bottom of the nest, with the usual exception of one or two farther forward. Only occasionally an empty shell would be found in the middle of an unhatched row. If the actual hatching of the eggs was observed in an opened nest several nymphs would usually be seen coming out at the same time, and in nearly all cases they were in neighboring eggs, though not always contiguous ones. So this rule of hatching, like most rules, is general but not binding.

The procedure of the female in placing the eggs leaves no doubt that the first laid ones are those at the bottom of the cell, showing that the order of laying has no relation to the order of hatching, except that it is mostly the reverse. It seems hardly reasonable to suppose that the eggs nearest the door are affected by greater heat or by a fresher supply of air, so I would suggest that the order of hatching may be due simply to the successive release of pressure along the tightly packed rows, giving the compressed embryos a chance to squirm and kick enough to split the inclosing shells. When hatching

once commences it proceeds very rapidly through the whole nest, showing that the eggs are all at the bursting point when the rupture of the first takes place.

In each lateral compartment of an egg nest the eggs (pl. 4, *E* and *F*) stand in two rows with their lower or head ends slanted toward the door. (It must be remembered that the punctures are made on the lower sides of the twigs, so that the eggs are inverted in their natural position in the nests.) On hatching, each egg splits vertically over the head and about one-third of the length along the back, but for only a short distance on the ventral side. As soon as this rupture opens the head of the young cicada bulges out, and then, by a bending of the body back and forth, the creature slowly works its way out of the shell, which, when empty, remains behind in its original place. The nymphs nearest the door have an easy exit, but those from the depths of the cell find themselves still in a confined space between the projecting ends of the empty shells ahead of them and the chamber wall, a passage almost as narrow as the egg itself, through which the delicate creatures must squirm to freedom.

Now, a newly hatched Orthopteron, or a newly hatched or newly born aphid, is done up in a tight-fitting garment with neither sleeves nor legs, and a young grasshopper hatching under the ground has a difficult journey to the surface. But nature has been more considerate in the case of the young cicada. It, too, comes out of the egg clothed in a skin-tight jacket, but this garment is not a mere bag, as with the other insects mentioned. Each is provided with special pouches for the appendages, or a part of them (fig. 8, 2). The incased antennae and the labrum project backward as three small points lying against the breast. The front legs are free to the bases of the femora, though so tightly held in their narrow sleeves that their joints have no independent motion. The middle and hind legs are also incased in long, slim sheathes, but they always adhere close to the sides of the body. Thus the creature newly hatched much resembles a tiny fish provided only with two sets of ventral fins, but when it gets into action its motions are comparable with the clumsy flopping of a seal stranded on the beach and trying to get back into the water (fig. 8, 3).

The infant cicada knows it is not destined to spend its life in the narrow cavern of its birth, or at least it has no desire to do so. With its head pointed toward the exit, it begins at once contortionistic bendings of the body, which slowly drive it forward. By throwing the head and thorax back the antennal tips and the front legs are made to project so that their points may take hold on any irregularity in the path. Then a contractile wave running forward through the abdomen brings up the rear parts of the body as the

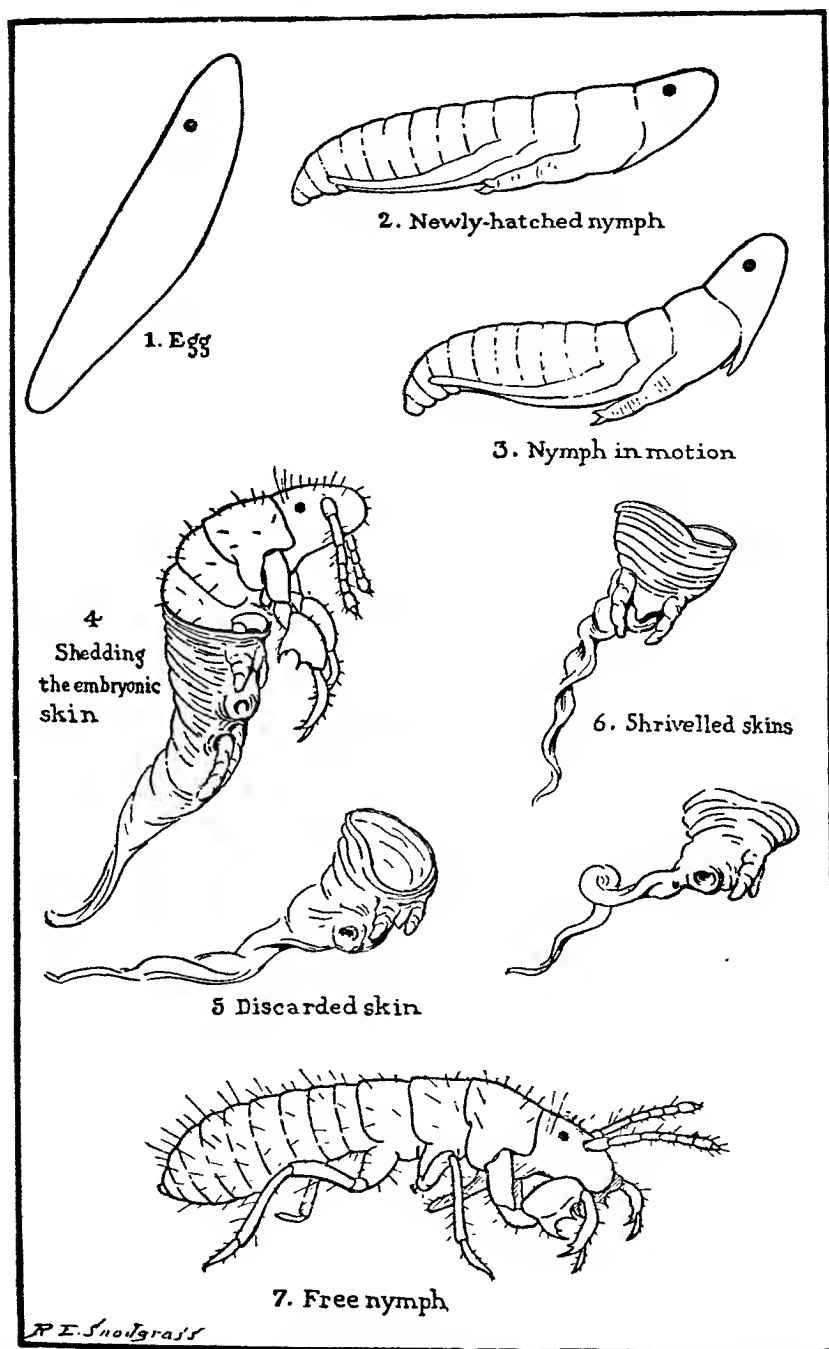


FIG. 8.—From the egg to the free nymph (greatly enlarged). The egg (1) shows the eye of the embryo near the upper end. The newly hatched nymph (2, 3) is enclosed in a tightly fitting skin which is shed (4) as soon as the creature emerges from the egg chamber. The discarded skin (5) shrivels (6) as the free young cicada or nymph (7) runs away.

front parts are again bent back, and the "flippers" grasp a new point of support. As these motions are repeated over and over again, the tiny, awkward thing painfully but surely moves forward, perhaps helped in its progress by the inclined tips of the flexible eggshells pressing against it, on the same principle that a head of barley automatically crawls up the inside of your sleeve.

Once out of the door no time is lost in discarding the encumbering garment, but it is never shed in the nest, under normal conditions. If, however, the nest is cut open and the hatching nymph finds itself in a free, open space, the embryonic sheath is cast off immediately, often the shedding begins while the posterior end of the insect's body is still in the egg and the skin may be left sticking in the open end of the shell. Probably where this has been recorded as the normal process the observations were made on eggs in opened chambers. If the young cicada did not have to gain its liberty through that narrow corridor, it might be born in a smooth bag as are its relations, the aphids.

Watching at the door of an undisturbed nest during a hatching day we soon see a tiny pointed head come poking out of the narrow hole. The threshold is soon crossed, but no more; this traveling in a bag is not a pleasure trip. A few contortions are always necessary to rupture the skin and sometimes several minutes are consumed in violent twistings and bendings before it splits. When it does break a vertical rent is formed over the top of the head, which latter bulges out till the cleft becomes a circle that enlarges as the entire head pushes through, followed rapidly by the body (fig. 8, 4). The appendages come out of their sheaths like fingers out of a glove, turning the pouches outside in. The antennæ are free first, they pop out and hang stiffly downward. Then the front legs are released and they hang stiff and rigid but quivering with a violent trembling. In a second or so this has passed, the joints double up and assume the characteristic attitude while they violently claw the air. Then the other legs and the abdomen come out and the embryo is a free young cicada (7). All this usually happens in less than a minute and the new creature is already off without even so much as a backward glance at the clothes it has just removed or at the home of its incubation period. Sentiment has no place in the insect mind.

As the nymphs emerge from the nest one after another and shed their skins the glistening white membranes accumulate in a loose pile before the entrance where they remain till wafted off on the breeze. Each discarded sheath has a goblet form (5, 6), the upper stiff part remaining open like a bowl, the lower part shrivelling to a twisted stalk. The antennal and labral pouches project from the skin as distinct appendages but those of the legs are usually inverted

during the shedding and disappear from the outside of the slough, though the holes where they were pulled in can be found before the membrane becomes too dry.

The nymph usually runs about at first in the groove of the twig containing its egg nest and then goes out on the smooth bark. Here any current of air is likely to carry it off immediately, but many wander about for some time, usually going toward the tips of the twigs, some even getting clear out on the leaves. But only a few nymphs are ever to be found on twigs where hundreds have recently hatched, as shown by the piles of embryonic skins; so it is evident that the great majority either fall off or are blown away very shortly after emerging. Many undoubtedly fall before the shedding of the egg membrane, for the inclosed creature has no possible way of holding on and even the free nymph has but feeble clinging powers. Those observed on twigs kept indoors often fell helplessly from the smooth bark while apparently making real efforts to retain their grasp. Their weak claws could get no grip on a hard surface. Instead, then, of deliberately launching themselves into space in response to some mysterious call from below (as usually described) the young cicadas simply fall from their birthplace by mere inability to hold on. But the same end is gained—they reach the ground, which is all that matters. Nature is ever careless of the means so long as the object is attained. Some acts of unreasoning creatures are assured by the giving of an instinct, others are forced by taking away the means of acting otherwise.

The cicada nymphs, like young scales, are at first attracted by the light. Those allowed to hatch on a table in a room left the twigs and headed straight for the windows 10 feet away. This instinct under natural conditions serves to entice them toward the outer parts of the tree, where they have the best chance of a clear drop to earth; but even so, adverse breezes, irregularity of the trees, underbrush and weeds can not but make their downward journey one of many a bump and slide from leaf to leaf before the earth receives them.

The creatures are too small to be followed with the eye as they drop, and so their actual course and their behavior when the ground is reached are not recorded. But several hatched indoors were placed on loose earth packed flat in a small dish. These at once proceeded to get below the surface. They did not dig in but simply entered the first crevice that they met in running about. If the first happened to terminate abruptly, the nymph came out again and tried another. In a few minutes all had found satisfactory retreats and remained below. The avidity with which they dived into any opening that presented itself indicates that the call to enter the earth is instinctive and

imperative with them once their feet have touched the ground. See, then, how within a few minutes their instincts shift to opposites. On hatching, their first effort is to extricate themselves from the narrow confines of the egg nest. It seems unlikely that enough light can penetrate the depths of this chamber to guide them to the exit, but once out and divested of their encumbering embryonic clothes they are irresistably drawn in the direction of the strongest light, even though this takes them upward, just the opposite of their destined course. But when this instinct has served its purpose and has taken the creatures to the port of freest passage to the earth, all their love of light is lost or swallowed up in the call to reenter some dark hole, narrower even than the one so recently left by such physical exertion.

When the young cicadas have entered the earth we practically have to say good-by to them till their return. Yet this recurring event is ever full of interest to us, for, as much as the cicadas have been studied, it seems that there is still plenty to be learned from them each time they make their visit to our part of the world.



FIG. 9.—Young cicada larva, or nymph, ready to enter the ground (greatly magnified).

ENTOMOLOGY AND THE WAR.¹

By Dr. L. O. HOWARD,

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Rather frequently during the past 18 months, meeting friends, they have said, by way of casual conversation, "I imagine that the war does not affect your work especially." They did not stop to think of the very great importance of insects in the carriage of certain diseases, the ease and frequency of such transfer becoming intensified wherever great bodies of men are brought together, as in great construction projects, and especially in great armies. They did not realize, entirely aside from the especial diseases of this character met with by the troops in Africa, Mesopotamia, and in the region of Salonica, that even upon the western front, in a good temperate climate, warfare under trench conditions was rendered much more difficult by reason of the prevalence of trench fever which investigations during the latter part of the war showed to be carried by the body-louse.

Moreover, with the same lack of thought which leads people to ignore the importance of the officers of the Quartermaster's Department as compared with those of the fighting arms of the service, they failed to consider, not only how damage by insects to growing crops influences the food supply of armies, but also how greatly grains and other foods stored for shipment to the front or on the way to the front may be reduced in bulk by the work of the different grain weevils and other insects affecting stored foods. In addition, they did not think of the damage done by insects to the timber which enters into the building of ships, into the manufacture of wings for the airplanes, and that which is used for oars, the handles of picks and spades, and which even occurs in such wooden structures and implements after they have been made—in the implements, not when in actual use, but rather in the period of storage and shipping. A striking example of this latter damage is seen in the history of the Crimean War, when England, after a long period of peace, provided the army which she sent to the Crimea with long-stored tools for the sappers and miners, and it was found that the handles crumbled through the work of *Lyctus* beetles.

¹ Reprinted by permission from the *Scientific Monthly*, February, 1919.

As a matter of fact, war conditions have intensified the work of the entomologists and have enabled them to make the importance of their researches felt almost as never before. Long before this country entered the war, the warring European nations had met with many of these problems in force. We know of the early ravages of typhus in the Balkans; we know of the loss through other insect-borne diseases in the eastern expeditions; and it is most interesting to realize that, although the need for the services of trained entomologists with the troops was not realized at first, later every sanitary unit in the British Expeditionary Forces carried two entomologists. Few people know that as early as 1915 there was a conference of all the principal official entomologists of Russia to consider the vital question of the loss to stored grains by weevils. Later this same matter was taken up by the British Government, and her best economic entomologist was sent out to Australia to endeavor to safeguard Australian wheat accumulating at the seaports for shipment to San Francisco, to be milled in this country to replace the milled grain which this country had sent to England (this route of shipment being chosen to avoid the long sea haul from Australia to England with possible added weevil damage during the journey, to say nothing of submarine dangers).

The story of the early efforts of the European governments to control the body lice which carry typhus, and, as found out later, trench fever, is interesting. Shipley in England published early papers and a book entitled "The Minor Horrors of War," in which everything that was known up to that time about lice was mentioned. In France, Houlbert published a pamphlet covering the same ground, and the women of France made an enormous number of camphor sachets for the troops to carry next their skin in order to deter lice. In Germany, Haase, stationing himself near a camp of Russian prisoners where living material was, to say the least, abundant, made, with that infinite attention to detail characteristic of the Germans, a careful study of the body louse, and published a sizable book giving the results of his investigations. Attention to important details is admirable, but when a writer devotes several illustrations and a minute description to the method by which a louse, accidentally finding itself on its back, resumes its normal position with the back upward, as Haase did, the practical reader is inclined to smile.

Later, however, much practical work was done by all these nations. Delousing stations were established; an admirable investigation of all aspects of the subject was carried on by Nuttall at the Quick Laboratories in Cambridge, England, and conditions were much improved before the United States troops began to mass and to be shipped across the Atlantic.

As will be remembered, one of the earliest matters taken up by the Congress of the United States after the declaration of war in April, 1917, was the consideration of appropriations for the stimulation of crop production, and in this consideration, naturally, one of the points was the control of the principal insect enemies of staple crops. Prior to any congressional action, however, the Bureau of Entomology started a country-wide reporting service on the conditions concerning these principal insect enemies, and engaged in excellent cooperation, not only all of the State entomologists, the entomologists of all of the agricultural experiment stations and the teachers of entomology in the colleges, but also the demonstration agents, the statistical agents, both State and Federal, the weather observers, and the field men of the Forest Service. The idea was to bring about as far as possible almost a census of insect damage and prospects, so that the earliest possible information should be gained as to any alarming increase in numbers of any given pest and that this information should be received at a common point (Washington) and distributed where it should be of the most good, and that it would enable repressive measures to be undertaken at the earliest possible moment in order to check the threatened loss. All reports received in this way were digested and were distributed all through the growing seasons of 1917 and 1918 to the official entomologists of the country.

Soon after this service was instituted the funds for food-crop stimulation became available, and trained men were employed for demonstration work to act in connection with the extension service of the department and of the different State colleges of agriculture. These men were assigned to different localities and took care of the demonstration work against the principal pests of staple crops all over the United States. Some of them were specialists in the insects which attack truck crops; others in those which damage field crops; others in those which affect orchards, and so on. Especial attention was given to the control of the grasshoppers which damage grain and forage crops and to the sweet-potato weevil, an insect which bids fair to seriously affect the output of the South of this important vegetable.

Aided, it is true, to a considerable extent by the winter of 1917-18, which from its unprecedented cold had a destructive effect upon many important insect pests, and to a lesser extent by the character of the winter of 1916-17, which also was a hard one for injurious insects, the economic entomologists, including the demonstrators, accomplished much. Owing to peculiar weather conditions in the early spring of 1917, certain insects not hitherto notably conspicuous appeared in great abundance and added new problems

to the production of certain crops. A notable example of such insects was the potato aphid, a species which previously had done almost no damage, but which appeared in countless numbers throughout certain of the Middle Western States in the early summer of that year. Notable work was done with the destruction of grasshoppers by the poisoned-bait method, and it is safe to say that many hundreds of thousands of dollars, perhaps millions of dollars, worth of food crops were saved in this unusually intensive work. A single instance among many may be given in more detail.

In the State of Kansas the season of 1918 was remarkable for one of the worst grasshopper outbreaks that have occurred in that State since 1913. The danger of this outbreak was recognized during the fall of 1917, and a grasshopper-egg survey was instituted in cooperation between the State Agricultural College and the Bureau of Entomology. The results of this survey showed that without doubt a great hatching of grasshoppers was imminent, and extensive cooperative plans were immediately made. Winter meetings were held throughout many of the counties in the western one-third of the State, and the farmers were organized and plans matured for the purpose of purchasing bran in large quantities, and then prompt distribution of poison was made as soon as the grasshoppers began to hatch. In eight counties of the State 36,000 pounds of white arsenic in 366 tons of wheat bran were used in the preparation of poison bait, which was distributed in an amount exceeding 900 tons. The counties cooperated in most cases financially. As a result of this general application of the bait, it appears that some 113,000 acres of wheat were saved from destruction. Estimating 14 bushels per acre, which is considered a full crop in western Kansas, with wheat at \$2 per bushel, this represents a value of approximately \$3,000,000 saved in Kansas. This figure is considered conservative, according to the officials of the State Agricultural College.

In addition to the control work on grasshoppers affecting wheat fields, it is estimated that 25,000 pounds of poison bait was used throughout Kansas for the purpose of protecting alfalfa and sugar beets, and it is estimated that 100,000 acres of alfalfa in western Kansas was saved by this application. With alfalfa selling at \$20 per ton, this represented \$2,500,000.

It should be mentioned incidentally that all this control work bids fair to be greatly hampered by the derangement of the insecticide situation in this country, due to war activities. Not only was the importation of arsenicals stopped, but their production was greatly limited by the fact that the smelters, from which arsenical compounds are gained as by-products, were so rushed in the production of urgently needed metal that by-product industries were largely

stopped, and by the further fact that more than a third of the actual production under these limitations was, toward the end, used by the Chemical Warfare Service. Nevertheless, the entomologists and the chemists and the insecticide manufacturers held frequent conferences as to how best to utilize the reduced quantity of arsenical insecticides to insure the protection of crops to the greatest extent possible, and it resulted that, although the amount of arsenic available was really insufficient to meet normal demands, yet by conservative use and better distribution the requirements of the farmers, fruitgrowers, gardeners, and others were met.

There might be mentioned also another side activity entirely due to war conditions. The extensive use of castor oil in airplane work made it necessary to grow the castor bean plant in great acreage in this country, since practically none was to be had elsewhere, the large Mexican crop having been bought up and sent to Spain, probably to secret German bases. Therefore, under Government contract, thousands of acres of this crop were planted in Florida and elsewhere. Now, although the castor-bean plant had not hitherto been known to be subject to serious insect attack, the planting of these large areas was immediately followed by the increase of certain injurious insects and by serious damage to the growing plants by the southern army worm and other species. Entomologists were at once called in, and through rapid and able work much of the threatened damage was prevented.

In the meantime the entomologists were able to be of service to the country, and especially to the military forces, in other ways. The damage to stored grain and to grain in shipment, which has been previously referred to, soon came to the front. Enormous quantities of grain and other materials were accumulated at the port of New York for shipment to Europe. The immense warehouses at the Bush Terminal in Brooklyn were centers of accumulation of such material. The Bureau of Entomology was called upon for advice by the War Department, and a laboratory was stationed at this terminal, where men experienced in the study of insect pests of this character were stationed, where competent inspection was made, and where arrangements were made for the proper fumigation or other treatment of stored products found to be infested with insects.

In addition to this work at the Bush Terminal in Brooklyn, experts on the Pacific coast and in the South were engaged in the inspection of many warehouses and mills where food supplies were stored, and throughout the entire period large supplies of food that were being seriously affected by insects were located. The owners of such supplies were advised of the necessity of prompt action in

order to avoid further losses and were shown how to prevent losses of newly acquired supplies that were free from insects.

The same sort of work was done in regard to insects affecting lumber and stored wooden implements. Early in 1917 a conference was held with representatives of the branches of the War and Navy Departments, Shipping Board, etc., which were responsible for the supplies drawn from the forest resources of the country. The object of this conference was to offer the services of the entomologists and to explain how they could help, through special investigations and advice, toward preventing serious losses of forest resources and damage by wood and bark boring beetles. Investigations of logging and manufacturing operations in Mississippi to meet the demand for ash oars, handles, and other supplies required by the war service showed, for example, that one company had lost more than 1,000,000 feet of ash logs through failure to provide for prompt utilization after the trees were cut, thus preventing the attack of the destructive ash-wood borers. Serious losses to seasoned ash and other hardwood sap material from "powder post," it was pointed out, could be prevented through the adoption of certain methods of management by the manufacturers and shippers with little or no additional cost.

The urgent demand for spruce for the construction of airplanes led to an exceptional effort by the Spruce Production Board to utilize the great resources represented by the Sitka spruce of the Pacific coast. It was soon realized that damage by wood-boring insects to the logs was a serious matter and that the advice of the expert entomologist was essential to prevent losses of the best material.

The problem was investigated by the entomologists, and it was found that the prevention of the damage and loss was a matter of methods of management in the logging operations and prompt utilization during a short period in the year when the insects were abundant.

Early in the war, and especially after the United States issued its declaration, the shortage of sugar made necessary an increase in the supply of supplemental sweets, and since none of these could be increased more economically and more promptly than honey, and since none of them have a higher value as food than honey, great efforts were made by the bee experts of the Bureau of Entomology to increase the honey production of the country. It was known that there was nectar available annually to provide for a profitable increase of ten or more times the then present honey crop, provided beekeepers were instructed in matters like proper wintering and disease control. So all apicultural investigational work, except that

on bee diseases, was discontinued and intensive extension work was begun. Specialists were sent out, held meetings, addressed more than 25,000 beekeepers, visited the apiaries, and gave personal instruction, with the result that the honey crop was greatly increased. Our exports of honey to allied countries have increased at least ten times over those of any period previous to the war, and in the meantime the domestic consumption of honey has greatly increased.

Returning once more to the important subject of medical entomology: During the period of the war the Bureau of Entomology maintained a thorough cooperation with the Office of the Surgeon General of the Army in the matter of experimental work on insect problems. Under the National Research Council's committee on medicine a sub-committee on medical entomology was established, of which the Chief of the Bureau of Entomology was made chairman, and Doctor Riley, of the University of Minnesota, and Doctor Brues, of the Bussey Institution of Harvard University, were the other members. Important work on the louse question was done by Doctors Moore and Hirschfelder, of the University of Minnesota, the former an entomologist and the latter a chemist, and by Doctor Lamson, of the Connecticut Agricultural College. Under this committee an enormous amount of experimental work was done with the different health problems in which insects are concerned.

For example, every suggestion that came to the War Department in regard to the control of the body louse was referred to the entomological committee or to the Bureau of Entomology, and those which were promising were experimentally tested, either at Washington or at Minneapolis, or for a time at New Orleans, where a branch laboratory was instituted. At the request of the Army War College and the Medical Department, as well as the Chemical Warfare Service, tests were made of a new poisonous gas. This led to extensive experiments in cooperation with the Chemical Warfare Service leading to the possible utilization of the gases used in warfare as fumigants for the control of insects and diseases. At the request of the Quartermaster's Corps a complete investigation was made of all of the processes of the American process of laundering adopted by the Army, and also of the dry-cleaning processes and the hat-repair processes. In these investigations the cooperation of the entomologists of the Bureau of Entomology with chemists of the Quartermaster's Corps resulted in the perfecting of the laundry processes so that it is now possible to guarantee the complete control of vermin in the laundry if the laundering is carried out according to the methods recommended, which are very slightly different from those in common use. It was found that the laundry machinery gave ample means for any sterilization of clothing necessary. In the in-

vestigations of the dry-cleaning processes it was found that the entire process gave complete control of vermin, but that gasoline treatment alone was not a perfect control. This discovery led to a long series of important studies of the effect of various densities of oils on insect eggs. At the request of the Chemical Warfare Service various substances and impregnated clothes devised for the protection of soldiers against gas were also tested as to their effects upon vermin. By a special request of the electro-therapeutic branch of the Office of the Surgeon General of the Army, investigations were made of a high-frequency generator as a control means against the body louse, and as a result of these investigations suggestion was made as to the possible application of high-frequency electric treatment for the control of scabies and other skin-infecting parasites. Cooperative investigations along this line are about to be taken up.

Among other problems investigated were the size of the meshes in mosquito bar necessary for the protection of cantonment buildings from disease-carrying mosquitoes; reports on the insects likely to be found injurious to troops sent to Siberia; investigations of the protective qualities against lice of furs dyed in various colors, and so on.

A series of lectures dealing with important sanitary problems from the insect side were mimeographed and were sent to persons in the Army, Navy, Public Health Service, and in civil life who were preparing themselves for or who were actively engaged in sanitary entomology.

Aside from this extensive cooperative research, entomologists were actually used in the Army, a number of them being given commissions while others acted as noncommissioned officers, assisting in the camp work on the control of insects that carry disease. The commissioning of expert entomologists for this kind of work was difficult, owing to the organization of the Army, but had the war continued, it is safe to say more and more entomologists would have been employed in this important work, whether commissioned or not. The records made by a number of these men were admirable and met with well-merited praise in Army circles. In great concentration camps in several instances entomologists were placed in entire charge of matters of mosquito and fly control under medical command or under sanitary engineers.

In addition to this cooperation with the Army itself, the Bureau of Entomology also cooperated with the Public Health Service, which had the extremely important work in charge of the health control of areas immediately surrounding the concentration camps, and held itself ready to assist in this work whenever called upon.

This statement of the work of the entomologists during the war might be extended very considerably. Many additional instances of the value of their labors might be detailed; but perhaps the impression which will be left by what has just been said will be quite as strong as if more facts were added and more time used.

Perhaps this is an opportunity, however, to call attention in a striking manner to the work which the economic entomologists are doing all the time. While all this other intensive work was going on, for example, the Federal entomologists were making a great fight in Texas by which the pink bollworm has apparently been absolutely wiped out in the districts in the United States infested last year and at the same time there has developed a system by which damage done by the cotton boll weevil can economically be greatly reduced, which may be said to be the culmination of the work of many years.

Incidentally it may be mentioned that the preeminently practical men who have, under the State and Federal Governments, been working for years in this extremely practical and important field, had supposed that the value of their work was generally recognized and that they were known to be scientifically trained and competent investigators whose advice and help meant everything in the warfare against insect life. But they were surprised and chagrined to find that even in certain high official circles the old idea of the entomologist still held—that he was a man whose life was devoted to the differentiation of species by the examination of the number of spines on the legs and the number of spots on the wings. The economic entomologists are thus evidently still unappreciated. Shall they change the name of their profession to avoid the survival of the old association with trivial things, or shall they work steadily on with the ultimate hope of gaining the confidence and respect even of the old-fashioned element of the people?

TWO TYPES OF SOUTHWESTERN CLIFF HOUSES.

By J. WALTER FEWKES,
Chief, Bureau of American Ethnology.

[With 6 plates.]

There are probably few areas in the United States where there is a greater contrast in physical features, fauna, and flora than southern Arizona and New Mexico on the one hand and the northern regions of the same, including contiguous portions of the adjacent States, Colorado and Utah, on the other. Each area has characteristic geological and biological peculiarities; the rivers partake of the same differences. The lower Gila through much of its course flows through a great stoneless plain conspicuous by its cacti, its spine-bearing trees, mesquites, and palo verde. Its northern tributaries rise in high mountains in which this desert vegetation gives place to characteristic genera where sagebrush, cedars, pines, and spruces replace the Mexican chaparral. Both areas show evidence of great erosion, forming canyons (pl. 1) with many natural caves in their walls.

The prehistoric human inhabitants of the two areas, as shown by the monuments left behind, also show marked peculiarities. Judged by his skill as a house builder, man reached a high development in both of these areas, but in both the mason's craft deteriorated and the culture of the builders was materially changed or disappeared before the advent of the white man. Theoretically there is a relation of cause and effect between these differences of environment and culture as indicated by architecture, and it is the object of this brief article to portray certain peculiarities in the character of cliff houses found in these geographical areas.

So far as we can interpret the history of man in the temperate zone, the oldest evidences of his presence occur in caves. Even before he built dwellings of stone he utilized caves as the best shelters his environment presented for that purpose. In the various steps in his advancement since that time he has lived in caverns, either natural or artificial, and often the construction of the buildings on these sites is noteworthy. What, in fact, would be more natural than that man in the early stages of his culture history should seek a cave or overhanging rock shelter for the protection of whatever food he

had accumulated? His intelligence would be less than that of the lower animals if he had not. For ages he may have been satisfied with the shelter nature thus afforded, but that complacency could not continue, for ambition always urged him to improve his condition; otherwise there would have been no subsequent civilization. He invented a better home; he early devised a walled-in structure, at first crude, afterwards more elaborate (pl. 2), even beautifying it to please his esthetic sense. He constructed buildings in the open, as necessity dictated, for caves are localized, and in its migrations the human race spread over grassland and plain as well as mountainous regions; but it may be said that the history of a savage race where caves exist naturally opens with the utilization of these sites by man for his comfort and for a place in which to keep his possessions. When the American Indian first came into the cave country of our Southwest he was, however, no savage; he had long dwelt in houses of some kind and had brought with him a gift of his gods, the food plant, maize, the cornerstone of his future development. This key to his civilization led him to avail himself of caves for his domicile, and there is objective material left by him at all stages of his evolution from which to trace the progress of the building from simple beginnings to the most elaborate construction to which he attained.

I have spoken above of maize, the supposed gift of the gods, which he brought to the cave country. The foundation of all culture is the maintenance of a food supply, and the first steps in the advancement of the human race were the discovery of an artificial means for increase and regulation of that supply. So long as man was dependent on the daily results of fishing or hunting he had scanty time to devote to advancement, but a domestication of animals or a discovery of food plants capable of being cultivated and preserved for future use, when necessary, started him upon an upward course to a higher culture.

The bulky food supply of various products of a vegetable nature requires storage after harvesting and the agriculturist is driven to seek out places to contain it or to construct bins for that purpose. Primitive man in a country where caves exist naturally utilized these shelters for that purpose. Here we have one of the most important reasons why the agricultural Indians of the mountains originally adopted caves for preservation of their food supply. The improvement of this shelter by the erection of bins naturally followed; consequently in studying the relations of cliff dwellings to man's development of our Southwest we should always have clearly in mind the storage of corn, which was so important under early conditions and the necessity for which survives to the present time.

The production of the food supply of an agricultural people is limited to a part of the year. From harvesting to planting the earth



Mark Daniels, Photographer.

CLIFF DWELLINGS, PUEBLO CANYON, SIERRA ANCHA, APACHE TRAIL, ARIZONA.



G. L. Bean, Photographer

Courtesy Denver and Rio Grande Railroad.

SPRUCE TREE HOUSE, MESA VERDE NATIONAL PARK, COLO.

yields nothing. Man then consumes an accumulated supply of food. Then it was that the cliff-house farmers retired to their caves, in which they had stored their corn, seeking whatever comfort was possible. Thus the cliff house (pl. 3) became the winter residence of the farmer. In the warm summer he could live in primitive brush lodges near his farm, but in winter he retired to his winter home in the cliffs, where, with abundant food at hand, it was possible for him to devote himself to improvements in his arts and the construction of better habitations; but above all, feeling the capriciousness of nature, upon which his future crops depended, and haunted by a fear that the gods would not be propitious in the coming year, he performed a ceaseless round of ceremonies to appease or control them.

Various theories have been propounded to explain why extensive community houses with elaborate ceremonial rooms were built in cliffs. We are told that they were constructed in inaccessible places for protection against foes. It has been suggested that cliff houses were horticultural outlooks, notwithstanding the most elaborate of them look out into deep canyons, devoid of soil and impossible as sites of farms. Cliff houses were primarily winter homes, protected from the elements by natural conditions and used primarily as storage places for food. Open-air pueblos were later constructed for the same purpose, and they also served as habitations during the long winter months.

Buildings in caves with stone walls occur almost everywhere in the world where man has advanced to any high degree of development. We find them in countries bordering the Mediterranean, dating back to the dawn of history; in Asia and Africa wherever geological conditions permit. Nor is the cliff dwelling necessarily a habitation which man has outgrown. In France, as shown by Mr. Baring Gould, these houses are still inhabited, and many additional examples might be mentioned from all over the world where men still live. All prehistoric or modern cliff dwellings are not built in the same form. They have a common site but greatly different construction. The cliff dwellings of the Far East are oriental buildings and those of the Dordogne in French caves are typical dwellings. American cliff houses are characteristic buildings of American aborigines. The dwellings in caves of the United States are practically confined to four States—Colorado, Utah, New Mexico, and Arizona—but even in this area, while they have the same site and superficially resemble each other, we find when their structure is studied that they differ. Two types may be readily recognized, one found in southern Arizona in the upper reaches of the Gila and Salt Rivers and their northern tributaries, the Verde and Tonto; the other in the northern part of the same State, and on the tributaries of the San

Juan in Utah and Colorado. The essential difference is the existence, in the latter, of a room specialized in form and structure for a distinct purpose, of which no homologue appears in the cliff houses of the Gila area. The differences that give us two great groups are so fundamental that when we examine the implements and domestic objects found in groups characterized in this way we find they also differ.

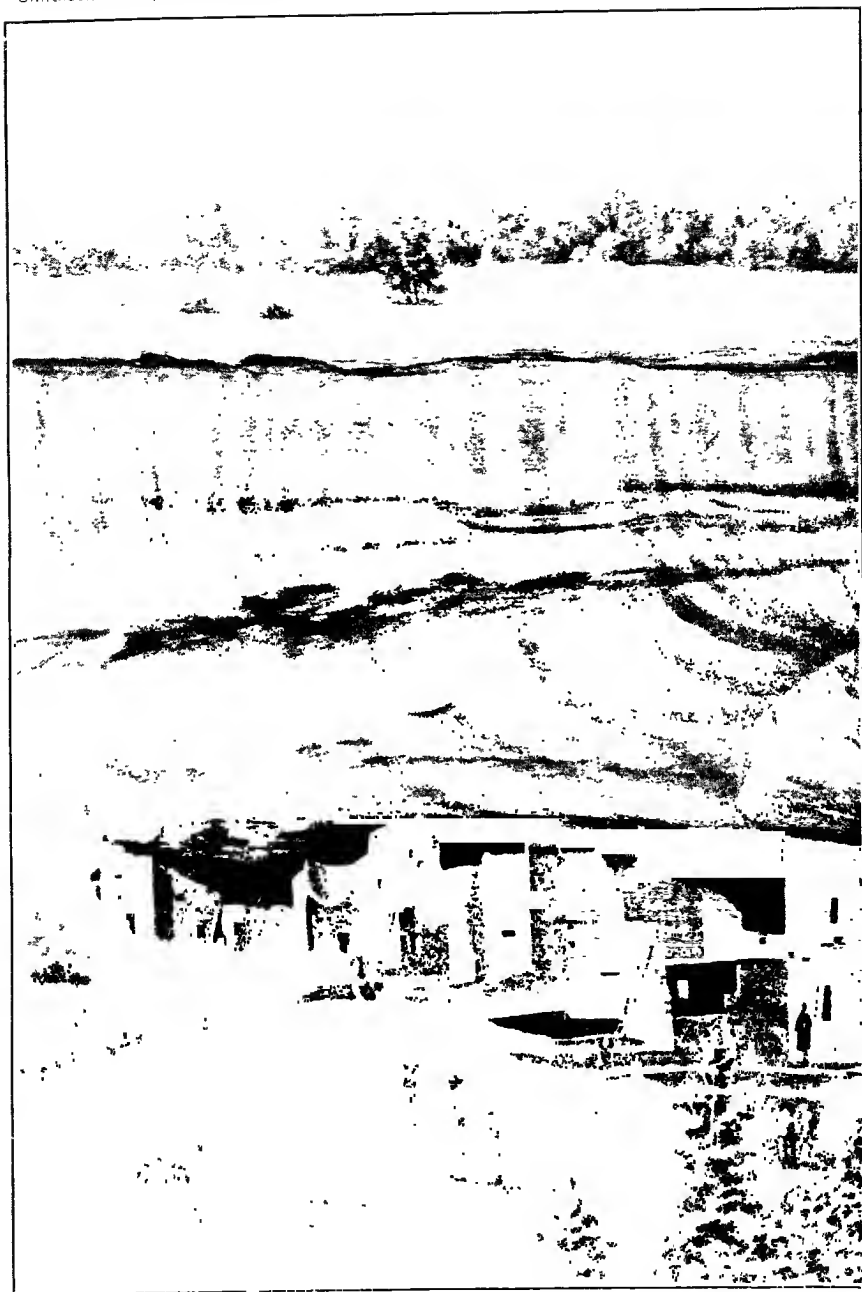
There are large cliff dwellings in the mountains of Chihuahua, Old Mexico. These resemble in their sites the cliff dwellings of the San Juan and those of the Gila, but differ from them in structure. They have no signs of circular rooms as the former, and, unlike both, have a peculiarly formed granary resembling a large inverted vase.

The cliff houses reached their highest development, so far as variety of rooms and excellency of masonry goes, in the Mesa Verde, Colorado. These cliff houses (pl. 4) are also distinguished from others in the Southwest by the form and character of specialized rooms. Here we find the most complicated form of specialized rooms, called kivas, with the best masonry and the most elaborate roofs. Moreover, a kiva of this form and structure is prehistoric, and practically disappeared before the written history of the Indians began. Its presence indicates the extent of one type of culture area, its absence another, and on the periphery where the two culture types overlap both become obscured or degenerated.

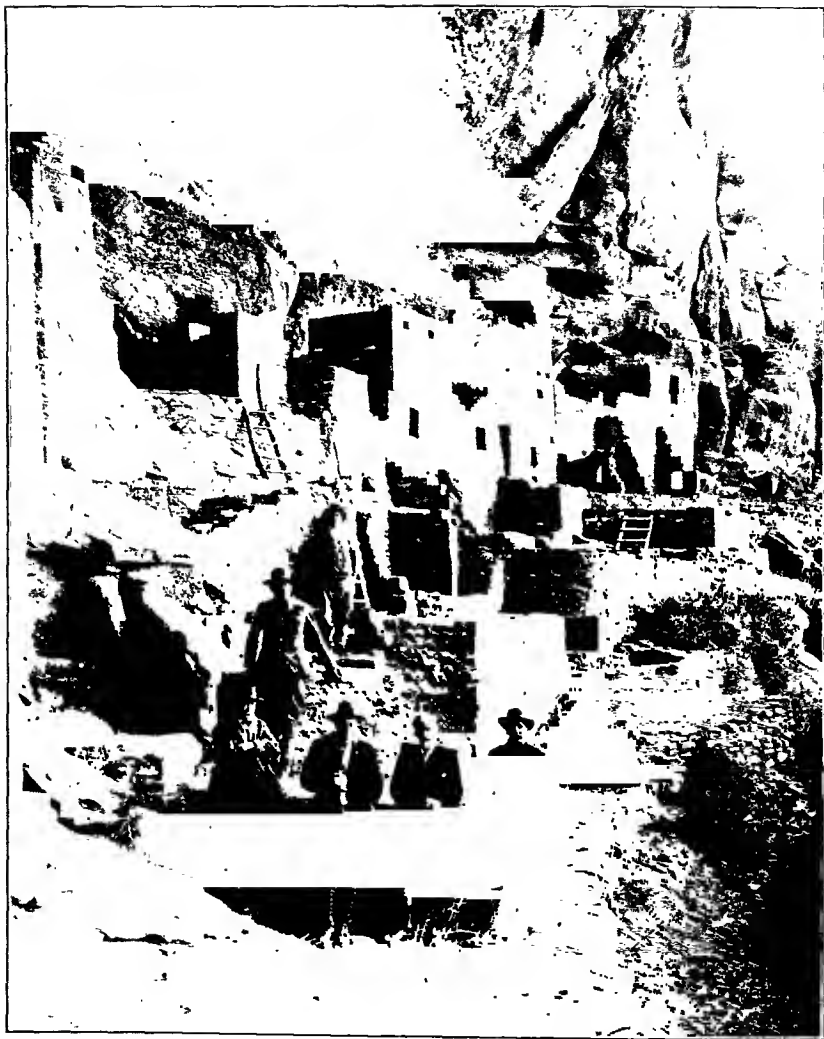
Taking, then, the circular form of the kiva as a characteristic feature, we may say that the southwestern cliff house has two forms; one with a kiva with a domed roof, the other with a flat roof; one constructed of regular horizontal, the other of irregular horizontal masonry; both forms were evolved from antecedent houses built of mud plastered on earth, or vertical undressed slabs of stone.

A second great group of cliff houses in the Southwest is that in which no circular kiva exists; where, in fact, no kiva of any form has yet been detected (pl. 5). As the circular kiva is limited to a definite geographic area, so the kivaless cliff houses are likewise confined to others. So far as site goes, they are alike, but their masonry is poorer and the objects in them are different. All these differences point to another kind of cliff dwelling, that of southern Arizona and southern New Mexico.

The deterioration of the circular kiva, or shall we say the arrested development of the same, appears in the region north of the Hopi, at Marsh Pass, and in the great ruin called "Kitseel" in the Navajo National Monument. Here the kiva loses the distinctive character of a vaulted roof and other features, still retaining, however, certain morphological elements, as the ceremonial floor opening, the ventilator, and the fire screen. It is simpler in form, but it is still a circular kiva.



SPRUCE TREE HOUSE, MESA VERDE NATIONAL PARK, COLO.



CLIFF PALACE, MESA VERDE NATIONAL PARK, COLO.



CLIFF DWELLINGS, COON CREEK, SIERRA ANCHA, APACHE TRAIL, COLO.



CLIFF HOUSE, GILA NATIONAL MONUMENT, ARIZ.

In a somewhat similar way in the modern circular kivas still used by the Rio Grande Pueblos the roof has not the complicated structure of the pure type of the Mesa Verde, but as in those of the Navajo Monument we are unable to say whether it has resulted from an arrested degenerate development. In the Mesa Verde we find a few examples of flat-roofed kivas, but only a sporadic example of the vaulted roof or prehistoric form occurs outside the basin of the upper San Juan.

The elaborate construction of the Mesa Verde kiva is thus adopted to distinguish one culture area of the Southwest, and wherever we find it we may be reasonably sure that the people who made it were akin.

A typical cliff dwelling of the southern type occurs on the upper Salt River, a tributary of the Gila, situated not far from Roosevelt Dam, and is shown in plate 6. This ruin, sadly in need of excavation and repair, is, however, protected by the Government and quite easily accessible from the Apache Trail. Although of large size, its ground plans show no circular or other room that can be identified as a kiva, the structural peculiarity that separates all the cliff dwellings of the Mesa Verde in the San Juan Valley from those of the Gila Basin.

What most strongly strikes the visitor to these southern cliff houses is their relation to environment. Not only the geological formation of the cave, but also the human habitations are characteristic. All rooms have right angles and are somewhat larger than those of the Mesa Verde cliff dwellings. The unusually thick layer of adobe plastering covering the inside and outside of the rooms is also characteristic of these ruins. Another good example of the southern type of cliff house is Montezuma Castle in the Valley of the Verde, a northern tributary of the Gila-Salt. The accompanying photograph (pl. 5) shows another example of the southern cliff house found in the Sierra Ancha, which belongs to the same type as that (pl. 6) near Roosevelt Dam. As examples of aboriginal masonry their walls are inferior to those of the Mesa Verde, but the hand of the plasterer has so concealed their imperfect masonry that externally they present a much better appearance.

Culturally the inhabitants of the southern type of cliff houses bear the same relation to those of great compounds like Casa Grande as people of Mesa Verde cliff houses do to those of Far View House, one of the pure pueblos in the Mummy Lake group. The great rectangular wall that incloses a ruin like Casa Grande is absent in these cliff houses for obvious reasons, and the material of which they are made is stone instead of earth, but the type of construction is the same. Transport the great cliff house near Roosevelt Dam to the stoneless plain bordering the Gila River or Tonto Creek and surround it by a

rectangular wall and we have the characteristic compound type of ruin.

It is evident that the cave sites of the cliff houses on the Salt River and its tributaries are similar to those of the northern tributaries of the San Juan, and yet the culture of the cliff dwellers was very different. The inference suggested by the presence of numerous kivas characteristic of the latter and their absence in the former is that while the inhabitants of a cliff dwelling without kivas may have had many complicated rites and certain rooms for that purpose we can hardly believe the ceremonies of this people were as elaborate.

There is no reason to doubt that the cliff houses of the Salt River as well as the great compounds of the neighboring valleys were prehistoric, or were probably without inhabitants when the early Spanish travelers entered the country. As in the Mesa Verde they reached a high development, declined, and disappeared, leaving only their monuments as evidence of their existence. In southern Arizona a people of a somewhat different culture from those of Mesa Verde developed an ability to construct large communal buildings, but their habitations were made of rude earth or logs like those of the historic Pima or Papagos. My conclusion is that the rise, culmination, and decline of two different phases of architecture occurred in two regions of the Southwest, each developing independently or along its own lines of growth. In the course of their history the inhabitants of these two areas increased in number and the horizon of each culture area coming in contact overlapped, forming a zone with characters of each. Here their descendants survived among the Hopi and Zuni up to our own time as a mixed people, still further modified by foreign influences retaining certain elements of each area. Survivals in the modern pueblos have brought to our time the *membra disjecta* of past phases of culture, and still have a great deal to teach us regarding the past.

ON THE RACE HISTORY AND FACIAL CHARACTERISTICS OF THE ABORIGINAL AMERICANS.

By W. H. HOLMES.

[With 14 plates.]

BIRTH OF THE RACE.

Among the many marvels that modern science has brought to light none is more wonderful and none less welcome than that which defines the place of man in the scheme of nature—his origin and his kinship, physical and intellectual, with the whole vast range of living things. It is made clear that the several races of man to-day represent the culminating stages of a branching series which connects back through simpler and still more simple ancestral forms to the primary manifestations of life in the remote past.

As outlined by the researches of the naturalist, the story of the becoming of the race is simply told. It is observed that the forms taken by the evolving life series were necessarily due largely to the environmental conditions under which they developed—that a world of waters molded forms fitted to live and move in the water, that a world of land developed distinct types accommodated to the conditions of the land, and that an environment comprising both land and water brought into existence types adjusted to both land and water. On the land there were further adaptations to special conditions of the particular environment. The inhabitants of the plains differed essentially from the inhabitants of the forests, for while the one employed the four members of the body in locomotion, the other used the feet to walk and the hands to climb and to do; and here is found the point of departure in the shaping up of the special being called man. Fitness for higher things was determined by the forest, for life among the branches and the vines developed the grasping hand, and the hand made man a possibility. The hands alone, however, were not responsible for the full result, since had the race continued to dwell in the forest man would to-day be merely a simple, undeveloped denizen of the woodland. The feet made the conquest of the earth possible. It is assumed that by reason of some undetermined contingency, such as great increase in population, the depletion of the forest food supply, or other gradually developing

cause, the children of the woodland cradle were compelled to seek their fortunes in the open, and the real struggle of existence began, the struggle that perfected the man. The grasping hands, freed from the forest and free to act independently of locomotion, led to the use of improvised implements in meeting foes, in preparing food, in constructing defenses and shelters, and finally to the shaping of tools, the initial step in the evolution of art, while the feet enabled their possessor to move with freedom in the pursuit of varied callings. Thus the hands, with the aid of the feet, directed by the rapidly developing brain, conquered the world.

SPECIALIZATION OF THE RACES.

Prolonged study of the available traces of man's origin and early movements as recorded in the book of books—the geologic strata—has led to the view that the natal place of the race must be sought somewhere in southern Asia or on the great islands of the southern seas. As conceived to-day, the outward movements of the human pioneer from the primeval home were at first and for a long time hesitating and slow. New conditions had to be met and diversified obstacles overcome, the exigencies of existence tending to develop the capacities of both brain and hand, and new environments to modify and emphasize the physical type of the isolated groups. We may think, for example, of certain groups of pioneers as they ventured into the open turning their faces to the west, occupying the valleys, skirting the shores of the inland seas, and climbing the intervening ranges until, in the fullness of time, the shores of the Atlantic were reached. Centers of population would develop at many points, and in western Europe traces of occupation recently uncovered date back to remote periods. From these centers expansion would take place in many directions. Not finding a passage to the western world beyond the shores of Britain, the populations would from necessity spread to the east, where they would encounter other currents spreading to the north from the primeval home over the vast expanse of central Asia, these latter representing the great Mongol race which to-day comprises, with its many blends, the majority of the human kind. Other currents from the southern home would pass to the east, occupying the shores of the chain of seas bordering the Pacific, peopling the countless islands that dot the waters, reaching in due course the far northeast, where further progress would be arrested by the broad expanse of open sea now known as Bering Strait. The differentiations of types gradually produced by early isolations would, as populations increased, be lessened by constant blending along the borders, and to-day the process of obliteration of race distinctions is progressing in ever-increasing ratio.

THE AMERICAN RACE.

In turning our attention to the American race, we study their facial characters in search of clues to their origin—their relationship with and their derivation from the complex of known peoples of the Old World. It is generally conceded that the red race is a new race as compared with the great races of the Old World. There have been found in America, after prolonged research, no certain traces of occupation extending back beyond a few thousand years; whereas, in the Old World there are abundant traces of human occupation whose age must be reckoned not in thousands, but in tens of thousands of years. The earliest skeletal remains in the New World are of men representing the perfected stage of physical development, the crania corresponding closely with those of civilized man; whereas, in the Old World the earliest finds are of forms hardly differentiated from the status of the higher apes.

It is not assumed that the pioneers of the Old World, who in following the tendency to wander reached the shores of Bering Sea, arrived in large numbers—that there was anything that could be called a migration, but that stragglers from Asiatic centers of population found their way across the intervening waters to the shores of America; and the process, continuing from century to century, involved not a single people nor a few more or less fully differentiated groups, but representatives of many of the brown-skinned peoples of the Asiatic shore land and of the islands of the Pacific and Indian Oceans. That some such process was involved is assumed from the fact that the American race to-day does not, as a whole, distinctly duplicate any known type of the Oriental groups, its homogenous character being due doubtless to a long period of race isolation, the diversified elements thus becoming blended into a new and distinctive people. It is probable that this condition was brought about or greatly accelerated by the eastern progress of the northern Asiatics, who for an indefinite period have occupied the shores of Bering Strait and Sea, blocking the way to the more southern groups.

FACIAL CHARACTERS AS A KEY TO ORIGIN.

Although there has been more or less blending of the Eskimo and the Indian along the line of contact from Alaska to Greenland, the two races in their totality stand well apart. The very pronounced gulf between them is well shown by comparison of the typical Indian of the northern interior (pl. 1, fig. 1, and pl. 2, fig. 1) with the typical Eskimo (pl. 1, fig. 2, and pl. 2, fig. 2), the latter type being characterized by the broad face and tilted eyes of the Mongol. The Indian, whose bold features stamp him as one of the ablest of the races,

occupies to-day the entire continent from the Eskimo boundary to Patagonia. We find no closely allied types in the adjacent Provinces of Asia, but there are approximations among the dark-skinned peoples of southern Asia, and probable kinship is suggested by plate 3, figures 1 and 2, the first a typical American Indian of New Mexico and the other a native of the island of Formosa. That the latter may be thought of as representing one of the groups which gave rise to the American race is reasonable, and relationships are further suggested by plates 4, 5, and 6. Here on the one hand we have a pair of young Apache Indians of Arizona and on the other two southern Asiatics, the one from the island of Sumatra and the other from the Philippines. That the facial evidence does not point to an exclusive island origin is suggested by a comparison of the face of the Navajo woman (pl. 7, fig. 1) with that of the Mongolian man shown in plate 7, figure 2. It is to be expected that with the incoming currents of Asiatic peoples there would be a considerable Mongol element, and this, though submerged, would tend to reappear. It should be noted, however, that Eskimo influence may have, in cases, extended as far south as the Navajo country.

The contrasting facial characters of the American Indian with the typical Asiatic Mongol is suggested by plate 8, figures 1 and 2, the first an Indian woman of the Great Plains and the second a Kalmuck of central Asia; and this contrast is still further emphasized by comparing the bold profile of a Cheyenne Indian (pl. 9, fig. 1) with that of a typical Mongolian (pl. 9, fig. 2).

In South America there appears no definite trace of the Mongol, the facial type being characteristically Indian. Plate 10, figure 1, and plate 11, figure 1, show typical Indian faces of to-day, and corresponding closely are certain skillfully modeled faces employed in embellishing earthen water bottles by the ancient Peruvians (pl. 10, fig. 2, and pl. 11, fig. 2). These striking physiognomies differ somewhat in form and expression from the incisive faces of the northern Indians, but show no definite traces of exotic admixture.

EXCEPTIONAL AMERICAN TYPES.

Notwithstanding the homogeneity in type of the Indian tribes from the Eskimo boundary on the north to Patagonia on the south, there are in the sculptured and modeled faces of ancient Mexico and Central America suggestions of facial conformation so distinctive and unusual that they have become the subject of much speculation, the problems involved being among the most interesting that have arisen regarding the history of man and culture in America. The problem to be solved is whether or not these exceptional features which appear in Toltec and Maya art are due to the intrusion of

Asiatic elements in comparatively recent centuries. The accompanying illustrations will sufficiently present the supposed evidence of foreign intrusion. Plate 1, figure 1, and plate 11, figure 1, illustrate physiognomies of normal Indian type. These are to be compared with plate 12, figure 1, which reproduces an ancient earthenware face of a type found in the State of Vera Cruz and believed to be of Aztec or Toltec origin. They were probably employed in the embellishment of earthen vessels or as architectural details. The well-modeled, smiling faces are broad and flat, with weak chins, and high cheek bones and distinctly narrow tilted eyes. Still more unusual are the faces shown in plate 12, figure 2, and plate 13, figure 1, sculptured heads of a type quite common as architectural embellishments in the ancient temples of Guatemala. In general contour the face contrasts strongly with that of the average Indian, the features lacking all the boldness and virility of the tribes of to-day. At the same time there is in the smooth, roundish, placid face, the small mouth, and in the tilted eyes a decided suggestion of the features of the Orient, and especially of the placid countenance so characteristic of sculptured images of Buddha (pl. 13, fig. 2). The suggestion of Asiatic influence is strengthened by a study of other ancient sculptural and architectural remains found in great plenty in Mexico and the Central American States. An example is shown in plate 14.

Numerous authors have found in these and other features of Maya sculpture convincing proof of the early introduction of Asiatic influence in Mexico and Central America, while other writers, with equal confidence, express the view that the features in question are without particular significance, being nothing more than normal variants of native types. The Maya peoples were exceedingly versatile and in their treatment of the human physiognomy were much given to the grotesque and humorous. This tendency was emphasized by the practice of introducing images of grotesque animistic deities into every phase of their sculptural and plastic art. The calm, well-modeled Buddhalike faces appear out of keeping with their vigorously modeled neighbors, and, if not portraits of individuals, they would seem at least to represent a well-marked and familiar facial type, whether native or otherwise. Mention may be made of other suggestive features of Maya culture which tend to support the theory of foreign influence. To one at all conversant with the architecture of the East Indies these Central American ruins have a familiar look not readily explained save on the theory of relationship in origin. This impression is not readily overcome, and it is further observed that the suggestion does not end with general effects, for the architectural details and especially the sculptural embellishments and the manner

of their application to the buildings confirm the impression. In the pose of figures the parallelism is truly remarkable, and that this parallelism could arise in two centers of culture (and two only) among totally isolated peoples occupying opposite sides of the globe challenges belief. It is further observed that in these ambitious structures there are suggestions of underlying crudeness as if the ideals of an advanced culture had been abruptly imposed upon the crude beginnings of a comparatively primitive people.

It is objected that in Maya art there are found no sculptured animal forms absolutely identical with those of the Old World. The elephant, for example, so important a sculptural subject in India, does not appear in these ruins, although there are snout-like features that suggest the trunk. On this point it should be noted that even if visits of Buddhistic priests are allowed, full identity in the sculptured forms of animals could hardly be expected, since the priests, devoted to the preaching of their doctrine, would hardly be architects, sculptors, or draftsmen, and the concepts introduced by them by word of mouth would from necessity be worked out by native sculptors, using life forms with which they were familiar or monsters drawn from their Pantheon of deities.

With respect to the manner in which elements of Asiatic culture could reach middle America in the early Christian centuries—the period of Buddhistic propagandism—it may be said that the sea-going capacity of the ships of that period was very considerable, and it is thus not impossible that by design or by accident Buddhistic devotees should have landed on the shores of America. Neither is it impossible that these devotees of a creed, determined to carry their doctrines to the ends of the earth, should have coasted eastern Asia, reaching the continent of North America by way of the Aleutian Islands. The journey from Alaska to middle America would be a long one, but not beyond the range of possible achievement for the fanatical devotees of Buddhism. The suggestion that the hypothetical sunken continent of the Pacific may have served as a bridge is deserving of but slight attention.

The writer of this sketch of a fascinating subject wishes to say in conclusion that he appreciates its shortcomings, for it is intended to be suggestive merely rather than final; but he finds gratification in the thought engendered by the study that whereas but a few generations ago our world outlook was exceedingly limited and our positive knowledge but a hint of the whole truth, the time is fast approaching as a result of the ever-widening scope of scientific research when we shall comprehend at a glance the world and its inhabitants, present and past, with the ease with which we now contemplate our local environment or with which we view a story thrown upon the screen.



1. AN AMERICAN INDIAN MAN. COMPARE WITH
FIGURE 2.



2. AN ESKIMO MAN OF ALASKA.



1. AN AMERICAN INDIAN WOMAN. COMPARE WITH
FIGURE 2.



2. AN ESKIMO WOMAN OF ALASKA.



1. A NAVAJO INDIAN WOMAN.



2. AN ASIATIC MONGOI.



1. A CHEYENNE INDIAN WOMAN. COMPARE WITH
FIGURE 2.



2. A KALMUCK WOMAN.



1. AN AMERICAN INDIAN PROFILE, FOR COMPARISON WITH FIGURE 2.



2. AN ASIATIC MONGOL PROFILE.

Smithsonian Report, 1919.—Holmes



1. AN AMERICAN INDIAN OF TO-DAY.



2. A PREHISTORIC PERUVIAN INDIAN, STRONGLY
MODELED IN CLAY.



1. A TYPICAL AMERICAN INDIAN, FOR COMPARISON
WITH FIGURE 2.



2. A PREHISTORIC PERUVIAN INDIAN, MODELED IN
CLAY.



1. A PREHISTORIC AZTEC FACE MODELED IN CLAY, FOR COMPARISON WITH TYPICAL INDIAN FACES.



2. A SCULPTURED HEAD OF THE ANCIENT MAYA INDIANS OF GUATEMALA.



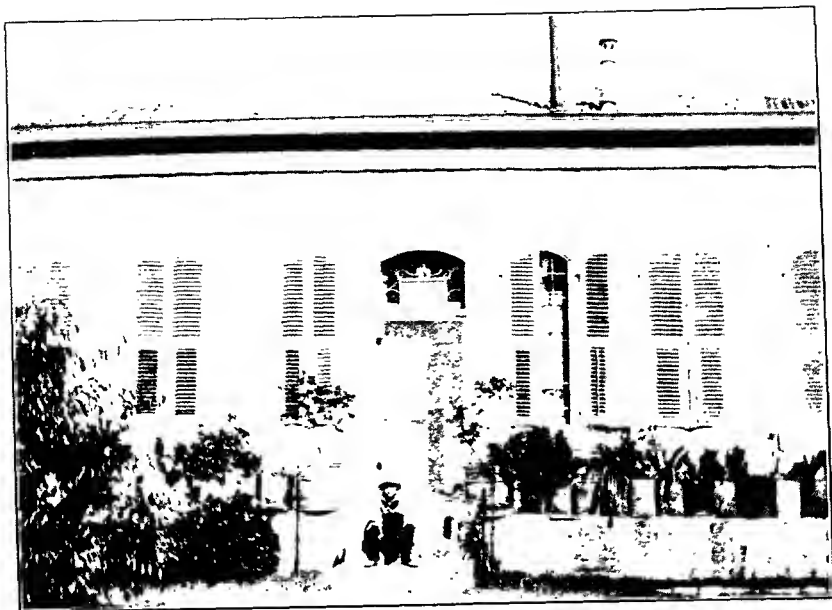
1. A REMARKABLE SCULPTURED FACE OF THE ANCIENT MAYA INDIANS, GUATEMALA, FOR COMPARISON WITH FIGURE 2.



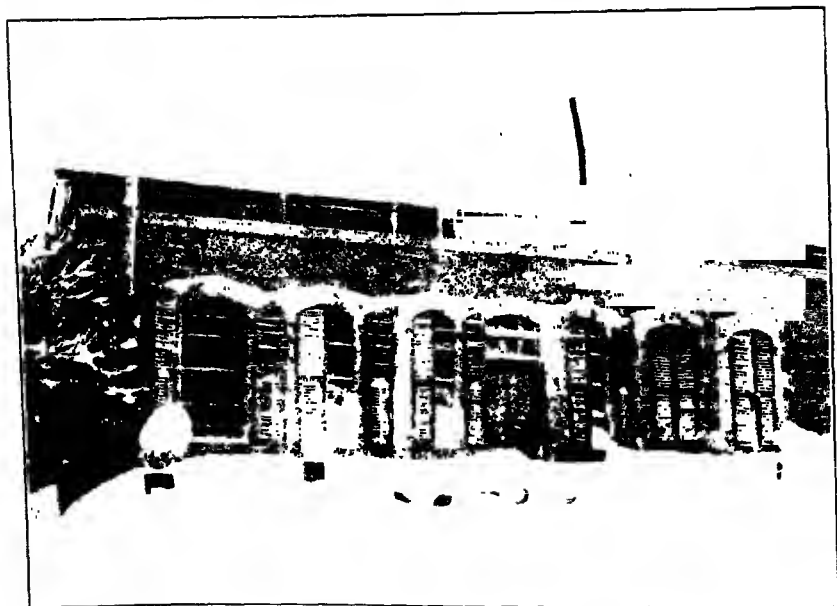
2. THE SCULPTURED FACE OF AN EAST INDIAN BUDDHA.



STUCCO MASTERPIECE, TEMPLE OF THE BEAU RELIEF, PALENQUE, YUCATAN.



1. PRESENT HOME OF AMERICAN SCHOOL IN JERUSALEM.



2. AMERICAN SCHOOL OF ORIENTAL RESEARCH, JERUSALEM. FEBRUARY 11, 1920. 29 TO 36 INCHES OF SNOW ON THE LEVEL.

THE OPPORTUNITY FOR AMERICAN ARCHEOLOGICAL RESEARCH IN PALESTINE.

By JAMES A. MONTGOMERY.

University of Pennsylvania and Philadelphia Divinity School.

[With 3 plates.]

One of the most distinguished of American archeologists, Prof. James H. Breasted, of the University of Chicago, has spoken of "the bridge of ancient civilization" that stretches like a great arc of a circle from the lands of Mesopotamia on the east to ancient Egypt on the southwest. This great arc follows the northerly course of the Euphrates Valley and bends around into the country we call Syria, which borders on the eastern shores of the Mediterranean and has the vast deserts of Arabia as its hinterland. At the two ends of this great curve lie the lands of the world's most ancient civilizations, Egypt and Babylonia. Archeologists dispute which of these is the older, but similarities and identities of culture show that there must have been active exchange of ideas and commodities between the two lands from earliest times, and we can confidently trace this intercommunication to 3000 B. C. and earlier. If Syria does not rank as one of the lands of original civilization, at least it was the exchange and meeting ground of the cultures of Babylonia and Egypt.

Also, politically and strategically Syria was always necessary to the ambitions of those great Empires. Egypt needed its buffer possession in Syria to protect its eagerly preserved isolation beyond the Isthmus of Suez. This strategical idea is continued to this day in the British claim to the proprietorship of Palestine. And from the other end the old Babylonian Empire, and later the Assyrian Empire, pushed forth by the logic of geography into the upper Euphrates Valley and then into the contiguous lands of Syria. In the mountains of Asia Minor on the north lurked fierce and barbarous peoples ready to descend on these young lands of civilization, and in Arabia roamed the nomads, ever preying on the settlements of peaceful life. We must remember that apart from the mere military lust of conquest those ancient civilizations insensibly extended their borders and threw their control over the bordering lands that were adaptable to civilization for the purpose of

protecting that civilization. This is the positive and beneficial argument that is still advanced by nations of higher culture in their attempt to control more barbarous areas, and this is an inherent trend of civilization that can not be too cavalierly dismissed as sheer self-seeking.

And Syria is a worthy prize of conquest and control. It is naturally a very rich land. It does not possess the unbounded agricultural wealth of Babylonia and Egypt, whose great rivers keep moist and fertile their vast plains. Syria is a country of hills and valleys, with alternating seasons of rain and drought. Its vegetation responds to these meteorological conditions. It was in antiquity a land of great forests, famous over the world particularly for its cedars, which supplied the timber of the palaces and temples of Egypt and Babylonia, even as the Bible tells us that Solomon brought thence the wood for his palatial buildings. It is a land of natural richness, the natural home of the vine, olive, and all kinds of fruit, while its soil is especially adapted to the raising of grain. Indeed it is the home, or one of the homes, of the parent stock of our wheat. The present denuded and miserable aspect of Palestine is due to the decay produced by the centuries-long misrule of the Turk. In its heyday, under the Roman Empire, Palestine must have resembled Italy, with its rich and fruitful vegetation. An honest government and a sensible economical direction will again make Syria not only self-supporting but a producer for the world.

There is one geographical aspect of Palestine which distinguishes it from Egypt and Babylonia. This is its great sea front along the Mediterranean. Babylonia always has been and always will be distinctly Asiatic. Actually to-day the British conquest of that land is administered from India. Egypt likewise is African. True, it came into the orbit of western civilization, partly through its own expansion, partly through conquest by western powers, from Alexander and on, but its civilization has always remained unique and detached from the rest of the world. The delta lands which gave the approach to the sea were not developed till a late date, and they were always carefully guarded against the incursions of barbarous peoples from across the sea. But the front of Syria is exposed to the west, and so has always taken its part in the civilization of the Mediterranean world, which is the parent of our western civilization. The early Minoan civilization of the eastern Mediterranean, which we now know to be as ancient almost as that of Egypt and Babylonia, greatly affected Syria. The Philistines, the doughty enemies of the Hebrews about 1000 B. C., were probably forerunners of the Hellenic races, and settled as pirates on the coast of Palestine. From about the same time is to be reckoned the first great Semitic push

westward in the trading vessels and stations of the Phœnician cities, which established their factories and colonies in a fringe about the great sea, even beyond the Strait of Gibraltar, as far as Britain and the west coast of Africa. With the rise of their maritime commerce and dominion the Greeks had these Syrian peoples to contend with, and later Rome fought a battle to the death with Carthage, the greatest of the Phœnician colonies. It must not be forgotten that Syria remained part of the western empire of Rome until the rise of Islam in the seventh century. And subsequently this control was renewed for two centuries in the Crusades, when Syria came again under western and Christian control and was divided into a number of Frankish kingdoms, patterned after the feudal administration of Europe. Although Islam regained its own again, nevertheless the presence of a large Christian population in Syria—six-sevenths of the people of Lebanon are Christians—has always kept the ties close knit with Europe, and the present French claims to the possession of central Syria are based on these ancient relations going back to the Crusades and the memories of the Roman Empire.

Syria, accordingly, has always been in close touch with the western world, far more, for instance, than Asia Minor, which projects farther into the European sphere. We Americans, with our idea that "Westward the course of empire takes its way," hardly realize the ancient bonds uniting the whole Mediterranean world, the west-bound Asiatic forces propelled from the Syrian coast and the east-bound forces of Europe claiming at least the western fringe of Asia as their own. But there is the further element of relationship which binds that Syrian land with the west. It is based on something stronger and deeper than commerce and politics and the lust of conquest. It is a sentiment, yet the most vital of human sentiments, namely, religion. Syria, or more exactly its southern section Palestine, is the home of the Bible and the Bible religions. The religion of Europe and America is Christian, and their lands trace their spiritual lineage back to Palestine. And likewise the religion of the Jews, that small but potential people, which has nested, despite vicissitudes of time and persecution, in the midst of Christendom, looks back with still older bonds to the same land, and with sentiments of race and affection that exceed those of the Christian. For the whole of the western world the little land of Palestine must share in the interest which the intelligent mind has for Greece and Rome, for from these three centers sprang the roots of our modern civilization.

The Bible is the book of that land. Its pages have been open to us for 2,000 years. It has been read and studied and interpreted to

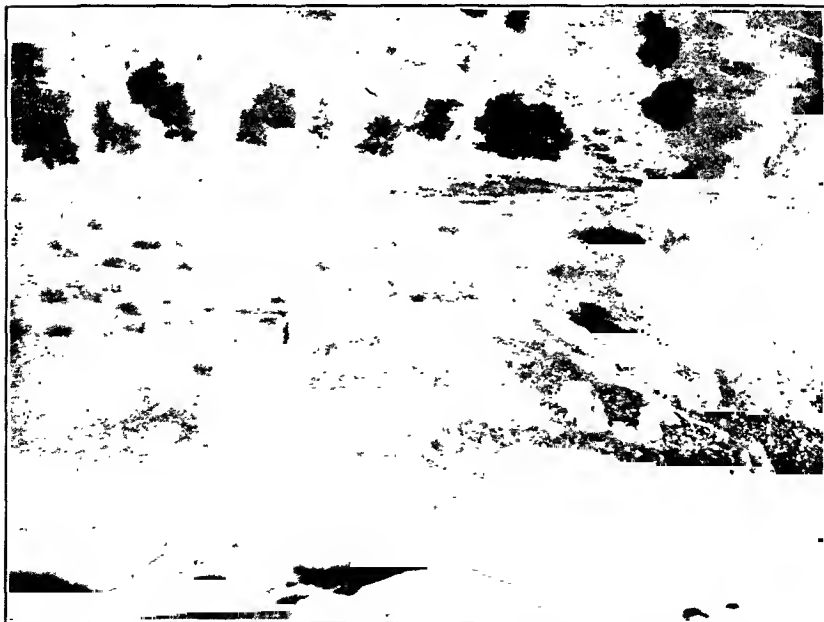
exhaustion, one might think, and yet it ever remains a fresh spring of knowledge and inspiration. This book will ever remain our chief source of information on Palestine's contribution to the spiritual good of the world. But the modern mind is no longer satisfied with merely the literature of a past age or civilization. It desires the ocular evidences of that past; it wishes to know how the people lived, what was their economy, their commerce, their architecture, their sanctuaries, their politics. We understand much when we read, we understand more when we see. Even in the case of a spiritual product like the Bible, which was not dependent upon and related to a mighty civilization, as in the case of Greece and Rome, we desire to know the material circumstances of that religious life and to learn what we may about its origins and conditions. This natural trend of the human mind, which is as old as Herodotus, has developed and made a science of the quest of archeology.

To-day the classical student does not feel he is equipped for his work unless he has visited the lands of Greece and Rome and spent a year or more visiting their remains and studying in their very atmosphere among the memorials of the mighty past. He will push his researches into the outlying lands of the classical world, into Asia Minor and Africa or northern Europe. And equally so for the civilizations of India and China, the student explores those lands for the vestiges of early times. In America has sprung up a native archeology in the exploration of the remains of the ancient civilizations of the continent, of the Mayas, Aztecs, Incas, and the cliff dwellers of our Southwest—the more fascinating research, for these peoples have left no written records, or at least none decipherable. In all these fields we have the lure of the history of man, of the quest of our beginnings as humanity. But of particular, almost practical, importance must be the archeological study of the ancient civilizations which have directly affected and molded our own, those which lie at the basis of our modern civilization.

In the case of the archeological investigation of Syria and Palestine there are fascinating problems before us. We may discover written documents coeval with the originals of our Bible books. These would throw immense light upon the many disputed critical questions as to the age and authenticity of those writings. If actual books of parchment or paper are not found, we may reasonably expect the discovery of stone and clay inscriptions, which would illuminate by written reference the history contained in the Bible. Such inscriptions always add to our knowledge of the Bible, sometimes indirectly, sometimes by direct reference to the characters and events of the Bible history. In any case they give us palpable evidence of the pulsating life of that ancient time, help us to realize the details of the sphere



1. LOT OWNED BY THE AMERICAN SCHOOL OF ORIENTAL RESEARCH, JERUSALEM.
MOUNT SCOPUS IN THE BACKGROUND.



2. ONE OF THE ALTARS OF MOLOCH IN THE VALLEY OF HINNOM.

of life in which that ancient people moved. The solid remains of architecture are to be laid bare. These will teach us the engineering and artistic abilities of the people, which we could not realize from written books. What appears to be a more minute line of investigation lies in the crumbled remains of domestic economy, the fragments of pottery and utensils; and yet these potsherds have revealed more to us than almost any other source. From the broken bits we can build up a picture of the whole object, we can learn how far advanced the people were in material ingenuity and artistic achievement. Also these slight objects enable us to trace the relations of civilization and to date the epochs of the strata according to the known chronologies of the better known histories of other lands. Much of such work is minutely scientific and painstaking and can not well be followed by the lay mind, but it is withal of indispensable value.

Then there are the remains of the ancient religious life, which, for Palestine, the home of our western religion, are obviously the most interesting subject of research. Ancient life was predominantly religious; it put forth its most enduring expression in the symbols of religion. In Egypt and Babylonia it is almost exclusively the temples and tombs that have yielded our greatest prizes, for apart from some royal palaces those buildings were the most enduringly built. And so everywhere in Palestine, wherever there was a human settlement, we find the remains of a sanctuary. These, to be sure, in that land were not ponderous temples, but rather very simple open-air structures, but as they were built of stone enough remains to picture the actual rites that were celebrated in the sanctuary and to make our inferences as to the ultimate religious beliefs. Also, as the concern for the dead was an integral part of the religion, the rock-hewn tombs and burial shafts are a prime source of knowledge for the archeologist, and in some cases, as with the magnificent so-called sarcophagus of Alexander, found at Sidon, they yield us remarkable finds in the way of art. In general, they throw light upon that most delicate form of human faith, the beliefs concerning the dead.

Peculiarly in Palestine the archeological remains are of value not so much in typifying the religion of the land which we associate with the Bible as in illustrating the environment out of which that religion grew and which was its foil and antagonist. The spiritual thought of the prophets and the psalmists, of Jesus Christ and His Apostles, never found, perhaps could not find, an expression in solid creations. In any case the Hebrews were not an architectural or artistic people and created no art of their own. Also the first Christian age built and left no memorials in stone, although for the later Christian history, from Constantine on, Syria is a land rich in memorials of the earliest Christian architecture, vying in this respect

with Rome and other Christian centers. But the land of the Old Testament and the New Testament left no contemporaneous symbols of its faith in architectural symbols which would stand for that faith as does Gothic art for medieval Europe. Rather, the remains in Palestine represent the primitive religion which the prophets fought, and for the New Testament we have the splendid temples of the Graeco-Roman religion, such as those at Baalbec and Palmyra, which reveal the actual conditions of the pagan world in which Christianity was born. But only the more keenly does archeology enable us to realize the triumphs which the religion of the Bible achieved in overcoming its pagan and often debased environment. The religion of the Old Testament and then that of the New won out in conflict with the mighty civilizations which constituted their environment and whose massive ruins remain as types and proofs of their greatness.

But apart from these various phases of archeological interest, the pursuit of archeology in Syria, as in any other ancient land, is chiefly of value for the world at large in enabling us to picture those ancient times. Because we think of the Bible as the Word of God we easily detach it from its original location in the world, and as a result we make it too unworldly. Even Palestine becomes for the believer a land that is not on this world's map, quite as unreal and mysterious as were Atlantis and Cathay, those lands of fable, to our forefathers. Archeology brings the home of the Bible nearer to us, makes it real and understandable, and so becomes an interpreter of the Bible. Just as archeology has been to us the greatest stimulus in the interpretation of Greek and Roman literature, so the same study should be of equal value for the home of the Bible.

Palestinian archeology has by no means been ignored; a great deal has already been accomplished in exploration and excavation. But it can not be said that Palestine has claimed anything like the attention paid to Babylonia and Egypt. America itself has contributed most important results in developing the archeology of those lands. But although their primary interest was largely due to the fact that they belonged to the biblical world, that Abraham came from the one and Moses from the other, the interest in Palestine as a land of research has never received its due.

America took the lead in Palestinian enterprise in Edward Robinson, of Union Seminary, New York City, who, in his two visits to Palestine in 1838 and 1852, is acknowledged to have established biblical geography on a scientific basis. Since then the countries of Europe have taken the lead. England has led, in the establishment of its Palestine Exploration Fund, the first society of the kind, in the mapping out of the country, and in pursuing the most complete and most numerous excavations. The Germans have been next in their

excavations and their innumerable monographs on every learned detail. The French have contributed very much, especially in the explorations of the lands on the fringe of Palestine. The Austrians have taken a part. In addition to the work of the British Exploration Fund the French have a most admirable Bible school at the Dominican convent in Jerusalem, and the Evangelical German Church has also its excellent school. Each of these institutions publishes its journals and researches, while another German society has a journal devoted to the Holy Land. Against this record for Europe America has not much to show except in the enterprise of individual scholars. It gave Robinson to the cause, and one of the most distinguished of the excavators for the British is an American, Dr. Frederick J. Bliss. The one great excavation work accomplished by American enterprise is that done at the ancient site of the ancient capital Samaria, undertaken by a Harvard expedition and financed by Mr. Jacob H. Schiff, of New York, in 1908-1910. These excavations have not yet been published, and so the general knowledge of the results has not been given to the world. One other very illustrious task has been accomplished by American scholarship, undertaken largely by Princeton scholars, the American Expedition to Syria in 1899-1900, and the Princeton Archeological Expeditions of 1904 and following. These explored the ruins in northern Syria and in the country east of the Jordan, and have found rich spoil in the remains of the Graeco-Roman civilization and of early Christianity.

As so little persistent and solid interest has been taken by us in America in Palestinian archeology, although we are far better acquainted with what has been done in Egypt and Babylonia, it may be well to give a résumé of what has been accomplished in that land.¹ In the first place, a great deal has been done and a great deal remains to be done in the way of surface exploration. Much remains on the top of the soil which is worthy of study; and especially in the outlying lands to the south and east of Palestine, bordering on the desert, there are innumerable sites which repay the study of the archeologist. Just before the war the Egyptian Exploration Fund made some most valuable researches in the Desert of Sin—that is, the land to the south of Judah. These revealed the extent to which the Graeco-Roman civilization had pushed itself far out into what are naturally desert lands. And the land to the east of the Jordan is full of ancient sites once important, even great cities, the centers of the trade routes which struck across the desert into Syria. The famous city of Palmyra, in the desert east of the center of Syria, is typical of this civilization: but there are many other cities, like

¹ A very useful review of archeological results in Palestine is to be found in G. A. Barton's *Archaeology and the Bible* (Philadelphia), pt. I.

Bostra and Jerash, across the Jordan, which tell the same story. And these lands have yielded a great wealth of inscriptions, Greek and Latin, and also Semitic, Nabataean, Palmyrene, and early Arabic.

In the line of actual excavation a goodly number of sites has already been broached in Palestine itself. The most extensive of these excavations is that of the British at Gezer, an ancient site on the border between Judah and Philistia. In the same region Lachish has been partly excavated, and some work done at such points as the biblical Gath and Beth-Shemesh. The very ancient city of Jericho has been in large part excavated by a German expedition. In the north, on the border of the Plain of Jezreel, or Esdraelon, the Austrians and Germans have accomplished good results at the biblical Megiddo and Taanach. The Germans were also beginning to excavate the ancient Shechem just before the war. The American excavations at Samaria have already been named. Thus a good deal has been accomplished, but the archeologist can regard these results only as first fruits, which stimulate his relish for more. Palestine is covered with the mounds of ancient cities, many of them identifiable as important in biblical history, which only await the spade to bring in a vast enlargement and rectification of biblical and oriental history.

The present would seem to be particularly the opportunity for American interest in biblical and oriental archeology to step in and preempt this rich field. Europe appears to be exhausted as a result of the Great War, but it is not out of the spirit of taking advantage of our neighbors' plight that we should take up this cause. Rather, it is because we should realize that the duty which has been mostly shouldered by the Europeans should be accepted by us as our duty. For since, in any case, we share in the benefits of the work, we should take our part in doing it.

There is an American institution which is prepared to act in this field if properly supported by American enterprise. This is the American School of Oriental Research in Jerusalem. It was established 20 years ago, and has had an honorable and useful history in its life so far. It has served primarily as a school for American scholars and students, giving them an opportunity for studying Palestine on the spot and under scientific direction. Each year some American scholar has gone out as director, accompanied by a small band of younger students, and by their experience and studies they have greatly vivified biblical and oriental learning at home. The school has not possessed the funds for intensive exploration, still less for the very expensive job of excavation, so it has not been able to make appeal through any spectacular results. But it is counting, especially now, upon a much larger support from America, so that it can be the center and exchange for American archeological enter-



1. COLONNADE AT SEBASTE, THE ANCIENT SAMARIA.



2. BROKEN TOMB IN THE VALLEY OF HINNOM SOUTH OF JERUSALEM.

prise in Palestine and Syria. From its experience it can promise rich results to any patrons of archeological results in that land.

Immediately after the war the administration of the school took steps to open it again. Prof. William H. Worrell, of the Hartford Seminary Foundation, was sent out as director last summer. He was accompanied by Prof. Albert T. Clay, of Yale University. These gentlemen were later joined by Prof. John P. Peters, of the University of the South, and Dr. William F. Albright, of Johns Hopkins University. The unsettled conditions of the country since the war have prevented these gentlemen from doing any aggressive work, but their observations and studies have been of great use, and it should be a satisfaction to all to know that this American school is open and in operation. For the year 1920-21 Dr. Albright remains as Director and with him are associated the Fellow (Dr. C. C. McCown, of the Pacific School of Religion) and other students.

The school is now housed in a pleasant rented building just outside of the city. It owns its own lot to the north of the city, and on this, as soon as the title deeds under the new government can be secured, it is planning to build the first unit of its buildings, using the sum of \$50,000 left by the late Mrs. James B. Nies, of Brooklyn, for this purpose. The school is under the patronage of the Archaeological Institute of America and the Society of Biblical Literature and Exegesis. The former corporation, incorporated under act of Congress, is the trustee for all its properties. Information concerning the school will be gladly given to any inquirers by the chairman of the executive committee, Prof. J. A. Montgomery, of the University of Pennsylvania, Philadelphia, or Prof. G. A. Barton, of Bryn Mawr College, Bryn Mawr, Pennsylvania. The other members of the Committee are President Cyrus Adler, of Dropsie College; Profs. B. W. Bacon, Albert T. Clay, and Charles C. Torrey, of Yale University; Prof. Morris Jastrow, jr., of the University of Pennsylvania; Dr. James B. Nies, of Brooklyn, and Prof. James H. Ropes, of Harvard University.

THE DIFFERENTIATION OF MANKIND INTO RACIAL TYPES.¹

By PROF. ARTHUR KEITH, M. D., LL. D., F. R. S.

For a brief half hour I am to try to engage your attention on a matter which has excited the interest of thoughtful minds from ancient times—the problem of how mankind has been demarcated into types so diverse as the Negro, the Mongol, and the Caucasian or European. For many a day the Mosaic explanation—the Tower of Babel theory—was regarded as a sufficient solution of this difficult problem. In these times most of us have adopted an explanation which differs in many respects from that put forward in the Book of Genesis; Noah disappears from our theory and is replaced in the dim distance of time by a “common ancestral stock.” Our story now commences not at the close of an historical flood but at the end of a geological epoch so distant from us that we can not compute its date with any degree of accuracy. Shem, Ham, and Japheth, the reputed ancestors of the three great racial stocks of modern times—the white, black, and yellow distinctive types of mankind—have also disappeared from our speculations; we no longer look out on the world and believe that the patterns which stud the variegated carpet of humanity were all woven at the same time; some of the patterns, we believe, are of ancient date and have retained many of the features which marked the “common ancestral” design; others are of more recent date, having the ancient pattern altered in many of its details. We have called in, as Darwin has taught us, the whole machinery of evolution—struggle for existence, survival of the fittest, spontaneous origin of structural variations, the inheritance of such variations—as the loom by which nature fashions her biological patterns. We have replaced the creative finger by the evolutionary machine, but no one is more conscious of the limitations of that machine than the student of human races. We are all familiar with the features of that racial human type which clusters round the heart of Africa; we recognize the Negro at a glance by his black, shining, hairless skin, his crisp hair, his flattened nose, his widely opened dark eyes, his heavily molded lips, his gleaming teeth and

¹ Opening address by the president of the anthropology section of the British Association Meeting at Bournemouth. Reprinted by permission from *Nature*, vol. 104, No. 2611, Nov. 13, 1919.

strong jaws. He has a carriage and proportion of body of his own; he has his peculiar quality of voice and action of brain. He is, even to the unpracticed eye, clearly different from the Mongolian native of northeastern Asia; the skin, the hair, the eyes, the quality of brain and voice, the carriage of body and proportion of limb to body serve to pick out the Mongol as a sharply differentiated human type. Different from either of these is the native of central Europe—the Aryan or Caucasian type of man: we know him by the paleness of his skin and by his facial features—particularly his narrow, prominent nose and thin lips. We are so accustomed to the prominence of the Caucasian nose that only a Mongol or Negro can appreciate its singularity in our Aryanized world. When we ask how these three types—the European, Chinaman, and Negro—came by their distinctive features, we find that our evolutionary machine is defective; the processes of natural and of sexual selection will preserve and exaggerate traits of body and of mind, but they can not produce that complex of features which marks off one racial type from another. Nature has at her command some secret mechanism by which she works out her new patterns in the bodies of man and beast—a mechanism of which we were almost ignorant in Darwin's day, but which we are now beginning to perceive and dimly understand. It is the bearing of this creative or morphogenetic mechanism on the evolution of the modern races of mankind which I propose to make the subject of my address.

Hid away in various parts of the human frame is a series of more or less obscure bodies or glands, five in number, which, in recent times, we have come to recognize as parts of the machinery which regulate the growth of the body. They form merely a fraction of the body—not more than one one-hundred-and-eightieth part of it; a man might pack the entire series in his watch pocket. The modern medical student is familiar with each one of them—the pituitary body, about the size of a ripe cherry, attached to the base of the brain and cradled in the floor of the skull: the pineal gland, also situated in the brain, and in point of size but little larger than a wheat grain: the thyroid in the neck, set astride the windpipe, forms a more bulky mass: the two suprarenal bodies situated in the belly, capping the kidneys, and the interstitial glands embedded within the substance of the testicle and ovary, complete the list. The modern physician is also familiar with the fact that the growth of the body may be retarded, accelerated, or completely altered if one or more of these glands become the seat of injury or of a functional disorder. It is 33 years now since first one woman and then another came to Dr. Pierre Marie in Paris seeking relief from a persistent headache and mentioning incidentally that their faces, bodies, hands,

and feet had altered so much in recent years that their best-known friends failed to recognize them. That incident marked the commencement of our knowledge of the pituitary gland as an intrinsic part of the machinery which regulates the shaping of our bodies and features. Dr. Marie named the condition "acromegaly." Since then hundreds of men and women showing symptoms similar to those of Dr. Marie's patients have been seen and diagnosed, and in every instance where the acromegalic changes were typical and marked there has been found a definite enlargement or tumor of the pituitary body. The practiced eye recognizes the full-blown condition of acromegaly at a glance, so characteristic are the features of the sufferers. Nay, as we walk along the streets we can note slight degrees of it—degrees which fall far short of the border line of disease; we note that it may give characteristic traits to a whole family—a family marked by what may be named an acromegalic taint. The pituitary gland is also concerned in another disturbance of growth—giantism. In every case where a young lad has shot up during his late teens into a lanky man of 7 feet or more—has become a giant—it has been found that his pituitary gland was the site of a disordered enlargement. The pituitary is a part of the mechanism which regulates our stature, and stature is a racial characteristic. The giant is usually acromegalic as well as tall, but the two conditions need not be combined; a young lad may undergo the bodily changes which characterize acromegaly and yet not become abnormally tall, or he may become—although this is rarely the case—a giant in stature and yet may not assume acromegalic features. There is a third condition of disordered growth in which the pituitary is concerned—one in which the length of the limbs is disproportionately increased—in which the sexual system and all the secondary sexual characters of body and mind either fail to develop or disappear—where fat tends to be deposited on the body, particularly over the buttocks and thighs—where, in brief, a eunuchoid condition of body develops. In all these three conditions we seem to be dealing with a disordered and exaggerated action of the pituitary gland; there must be conditions of an opposite kind where the functions of the pituitary are disordered and reduced. A number of cases of dwarfism have been recorded where boys or girls retained their boyhood or girlhood throughout life, apparently because their pituitary gland had been invaded and partly destroyed by tumors. We shall see that dwarfism may result also from a failure of the thyroid gland. On the evidence at our disposal, evidence which is being rapidly augmented, we are justified in regarding the pituitary gland as one of the principal pinions in the machinery which regulates the growth of the human body and is directly concerned in determining stature, cast of features, texture

of skin, and character of hair—all of them marks of race. When we compare the three chief racial types of humanity—the Negro, the Mongol, and the Caucasian or European—we can recognize in the last named a greater predominance of the pituitary than in the other two. The sharp and pronounced nasalization of the face, the tendency to strong eyebrow ridges, the prominent chin, the tendency to bulk of body and height of stature in the majority of Europeans, is best explained, so far as the present state of our knowledge goes, in terms of pituitary function.

There is no question that our interest in the mechanism of growth has been quickened in recent years by observations and discoveries made by physicians on men and women who suffered from pituitary disorders, but that a small part of the body could influence and regulate the growth and characterization of the whole was known in ancient times. For many centuries it has been common knowledge that the removal of the genital glands alters the external form and internal nature of man and beast. The sooner the operation is performed after birth, the more certain are its effects. Were a naturalist from a unisexual world to visit this earth of ours it would be difficult to convince him that a brother and a sister were of the same species, or that the wrinkled, sallow-visaged eunuch with his beardless face, his long, tapering limbs, his hesitating carriage, his carping outlook, and corpulent body was brother to the thick-set, robust, pugilistic man with the bearded face. The discovery that the testicle and ovary contain, scattered throughout their substance, a small glandular element which has nothing to do with their main function—the production of genital cells—was made 70 years ago, but the evidence which leads us to believe that this scattered element—the interstitial gland—is directly concerned in the mechanism of growth is of quite recent date. All those changes which we may observe in the girl or boy at puberty—the phase of growth which brings into full prominence their racial characteristics—depend on the action of the interstitial glands. If they are removed or remain in abeyance the maturation of the body is both prolonged and altered. In seeking for the mechanism which shapes mankind into races we must take the interstitial gland into our reckoning. I am of opinion that the sexual differentiation—the robust manifestations of the male characters—is more emphatic in the Caucasian than in either the Mongol or Negro racial types. In both Mongol and Negro, in their most representative form, we find a beardless face and almost hairless body, and in certain Negro types, especially in Nilotic tribes, with their long, storklike legs, we seem to have a manifestation of abeyance in the action of the interstitial glands. At the close of sexual life we often see the features of a woman assume a coarser and more masculine appearance.

Associated with the interstitial glands, at least in point of development, are the suprarenal bodies or glands. Our knowledge that these two comparatively small structures, no larger than the segments into which a moderately sized orange can be separated, are connected with pigmentation of the skin dates back to 1854, when Dr. Thomas Addison, a physician to Guy's Hospital, London, observed that gradual destruction of these bodies by disease led to a darkening or pigmentation of the patient's skin, besides giving rise to other more severe changes and symptoms. Now, it is 150 years since John Hunter came to the conclusion, on the evidence then at his disposal, that the original color of man's skin was black, and all the knowledge that we have gathered since his time supports the inference he drew. From the fact that pigment begins to collect in and thus darken the skin when the suprarenal bodies become the seat of a destructive disease we infer that they have to do with the clearing away of pigment and that we Europeans owe the fairness of our skins to some particular virtue resident in the suprarenal bodies. That their function is complex and multiple the researches of Sir E. A. Sharpey Schafer, of T. R. Elliott, and of W. B. Cannon have made very evident. Fifteen years ago Bulloch and Sequeira established the fact that when a suprarenal body becomes the site of a peculiar form of malignant overgrowth in childhood the body of the boy or girl undergoes certain extraordinary growth changes. The sexual organs become rapidly mature, and through the framework of childhood burst all the features of sexual maturity—the full chest, muscularity of limbs, bass voice, bearded face, and hairy body—a miniature Hercules—a miracle of transformation in body and brain. Corresponding changes occur in young girls—almost infants in years—with a tendency to assume features which characterize the male. Prof. Glynn (Quart. Journ. of Med., vol. v, p. 157, 1912) has recently collected the details to such cases and systematized our knowledge of these strange derangements of growth. There can be no doubt that the suprarenal bodies constitute an important part of the mechanism which regulates the development and growth of the human body and helps in determining the racial characters of mankind. We know that certain races come more quickly to sexual maturity than others and that races vary in development of hair and of pigment, and it is therefore reasonable to expect a satisfactory explanation of these characters when we have come by a more complete knowledge of the suprarenal mechanism.

During the last few years the totally unexpected discovery has been sprung upon us that disease of the minute pineal gland of the brain may give rise to a train of symptoms very similar to those which follow tumor formation of the cortex of the suprarenal bodies. In some instances the sudden sexual prematurity which occurs in childhood is apparently the immediate result of a tumorlike affection of

the pineal gland. We have hitherto regarded the pineal gland, little bigger than a wheat grain and buried deeply in the brain, as a mere useless vestige of a median or parietal eye, derived from some distant human ancestor in whom that eye was functional, but on the clinical and experimental evidence now rapidly accumulating we must assign to it a place in the machinery which controls the growth of the body.

We come now to deal with the thyroid gland, which, from an anthropological point of view, must be regarded as the most important of all the organs or glands of internal secretion. Here, too, in connection with the thyroid gland, which is situated in the front of the neck, where it is so apt to become enlarged and prominent in women, I must direct attention to a generalization which I slurred over when speaking of the pituitary and suprarenal glands. Each of these glands throws into the circulating blood two sets of substances—one set to act immediately in tuning the parts of the body which are not under the influence of the will to the work they have to do when the body is at rest and when it is making an effort; another set of substances—which Prof. Gley has named morphogenetic—has not an immediate but a remote effect; they regulate the development and coordinate the growth of the various parts of the body. Now, so far as the immediate function of the thyroid is concerned, our present knowledge points to the gland as the manufactory of a substance which, when circulating in the body, regulates the rate of combustion of the tissues; when we make a muscular effort, or when our bodies are exposed to cold, or when we become the subjects of infection, the thyroid is called upon to assist in mobilizing all available tissue fuel. If we consider only its immediate function it is clear that the thyroid is connected with the selection and survival of human races. When, however, we consider its remote or morphogenetic effects on growth, its importance as a factor in shaping the characteristics of human races becomes even more evident. In districts where the thyroid is liable to that form of disease known as goitre it has been known for many a year that children who were affected became cretins—dwarf idiots with a very characteristic appearance of face and body.² Disease of the thyroid stunts and alters the growth of the body so that the subjects of this disorder might well be classed as a separate species of humanity. If the thyroid becomes diseased and defective after growth of the body is completed, then certain changes, first observed by Sir William Gull in 1873, are set up and give rise to the disordered state of the body known as myxœdema. "In this state," says Sir Malcolm Morris (*Brit. Med. Journ.*, i., p. 1038, 1913), "the skin is cold, dry, and rough, seldom or never perspires, and may take on a yellowish tint; there is a bright red flush in the malar region.

² The story of the discovery of the action of the thyroid gland is told by Prof. G. M. Murray, *Brit. Med. Journ.*, ii., p. 163, 1913.

The skin as a whole looks transparent; the hair of the scalp becomes scanty; the pubic and axillary hair, with the eyelashes and eyebrows, often falls out; in many cases the teeth are brittle and carious. All these appearances disappear under the administration of thyroid extract." We have here conclusive evidence that the thyroid acts directly on the skin and hair, just the structures we employ in the classification of human races. The influence of the thyroid on the development of the other systems of the body, particularly on the growth of the skull and skeleton, is equally profound. This is particularly the case as regards the base of the skull and the nose. The arrest of growth falls mainly on the basal part of the skull, with the result that the root of the nose appears to be flattened and drawn backwards between the eyes, the upper forehead appears projecting or bulging, the face appears flattened, and the bony scaffolding of the nose, particularly when compared with the prominence of the jaws, is greatly reduced. Now, these facial features which I have enumerated give the Mongolian face its characteristic aspect, and, to a lesser degree, they are also to be traced in the features of the Negro. Indeed, in one aberrant branch of the Negro race—the Bushman of South Africa—the thyroid facies is even more emphatically brought out than in the most typical Mongol. You will observe that, in my opinion, the thyroid—or a reduction or alteration in the activity of the thyroid—has been a factor in determining some of the racial characteristics of the Mongol and the Negro races. I know of a telling piece of evidence which supports this thesis. Some years ago there died in the East End of London a Chinese giant—the subject, we must suppose, of an excessive action of the pituitary gland—the gland which I regard as playing a predominant part in shaping the face and bodily form of the European. The skeleton of this giant was prepared and placed in the museum of the London Hospital Medical College by Col. T. H. Openshaw, and anyone inspecting that skeleton can see that, although certain Chinese features are still recognizable, the nasal region and the supra-orbital ridges of the face have assumed the more prominent European type.

There are two peculiar and very definite forms of dwarfism with which most people are familiar, both of which must be regarded as due to a defect in the growth-regulating mechanism of the thyroid. Now, one of these forms of dwarfism is known to medical men as achondroplasia, because the growth of cartilage is particularly affected, but in familiar language we may speak of the sufferers from this disorder of growth as being of the "bulldog breed" or of the "dachshund breed." In the dachshund the limbs are greatly shortened and gnarled, but the nose or snout suffers no reduction, while in the bulldog the nose and nasal part of the face are greatly reduced and withdrawn, showing an exaggerated degree of Mongolism.

Among achondroplastic human dwarfs both breeds occur, but the "bulldog" form is much more common than the "dachshund" type. The shortening of limbs with retraction of the nasal region of the face—pug-face, or prosopia, we may call the condition—has a very direct interest for anthropologists, seeing that short limbs and a long trunk are well recognized racial characteristics of the Mongol. In the second kind of dwarfism, which we have reason to regard as due to a functional defect of the thyroid, the Mongolian traits are so apparent that the sufferers from this disorder are known to medical men as "Mongolian idiots," for not only is their growth stunted but their brains also act in a peculiar and aberrant manner. Dr. Langdon Down, who gave the subjects of this peculiar disorder the name "Mongolian idiots" 55 years ago, knew nothing of the modern doctrine of internal secretions, but that doctrine has been applied in recent years by Dr. F. G. Crookshank (*The Universal Medical Record*, vol. iii, p. 12, 1913) to explain the features and condition of Mongoloid imbecile children. Some years ago (*Journ. of Anat. and Physiol.*, 1913) I brought forward evidence to show that we could best explain the various forms of anthropoid apes by applying the modern doctrine of a growth-controlling glandular mechanism. In the gorilla we see the effects of a predominance of the pituitary elements; in the orang, of the thyroid. The late Prof. Klaatsch tried to account for the superficial resemblances between the Malay and the orang by postulating a genetic relationship between them; for a similar reason he derived the Negro type from a gorilline ancestry. Occasionally we see a man or woman of supposedly pure European ancestry displaying definite Mongoloid traits in their features. We have been in the habit of accounting for such manifestations by the theory, at one time very popular, that a Mongoloid race had at one time spread over Europe and that Mongoloid traits were atavistic recurrences. An examination of the human remains of ancient Europe yields no evidence in support of a Turanian or Mongol invasion of Europe.

All these manifestations to which I have been directing your attention—the sporadic manifestation of the Mongoloid characters in diseased children and in healthy adult Europeans, the generic characters which separate one kind of ape from another, the bodily and mental features which mark the various races of mankind—are best explained by the theory I am supporting, namely, that the conformation of man and ape and of every vertebrate animal is determined by a common growth-controlling mechanism which is resident in a system of small but complex glandular organs. We must now look somewhat more closely into the manner in which this growth-regulating mechanism actually works. That we can do best by taking a glimpse of a research carried out by Bayliss and Starling in the open-

ing years of the present century. They were seeking to explain why it was that the pancreas poured out its digestive juice as soon as the contents of the stomach commenced to pass into the first part of the duodenum. It was then known that if acid was applied to the lining epithelial membrane of the duodenum the pancreas commenced to work; it was known also that the message which set the pancreas into operation was not conveyed from the duodenum to the pancreas by nerves, for when they were cut the mechanism was still effective. Bayliss and Starling solved the puzzle by making an emulsion from the acid-soaked lining epithelium of the duodenum and injecting the extract of that emulsion into the circulating blood. The result was that the pancreas was immediately thrown into activity. The particular substance which was thus set circulating in the blood and acted on the pancreas, and on the pancreas alone, and thus served as a messenger or hormone they named secretin. They not only cleared up the mechanism of pancreatic secretion, but at the same time made a discovery of much greater importance. They had discovered a new method whereby one part of the human body could communicate with and control another. Up to that time we had been like an outlandish visitor to a strange city, who believed that the visible telegraph or telephone wires were the only means of communication between its inhabitants. We believed that it was only by nerve fibers that intercommunication was established in the animal body. Bayliss and Starling showed that there was a postal system. Missives posted in the general circulation were duly delivered at their destinations. The manner in which they reached the right address is of particular importance for us: we must suppose that the missive or hormone circulating in the blood and the recipient for which they are intended have a special attraction or affinity for each other—one due to their physical constitution—and hence they, and only they, come together as the blood circulates round the body. Secretin is a hormone which effects its errand rapidly and immediately, whereas the growth or morphogenetic hormones thrown into the circulation by the pituitary, pineal, thyroid, suprarenal, and genital glands act slowly and remotely. But both are alike in this; the result depends not only on the nature of the hormone or missive but also on the state of the local recipient. The local recipient may be specially greedy, as it were, and seize more than a fair share of the manna in circulation, or it may have "sticky fingers" and seize what is not really intended for local consumption. We can see that local growth—the development of a particular trait or feature—is dependent not only on the hormones supplied to that part but also on the condition of the receptive mechanism of the part. Hence we can understand a local derangement of growth, an acromegaly or gigantism confined to a finger or to the eyebrow ridges, to the nose,

to one side of the face, and such local manifestations are not uncommon. It is by a variation in the sensitiveness of the local recipient that we have an explanation of the endless variety to be found in the relative development of racial and individual features.

Some 10 years after Starling had formulated the theory of hormones, Prof. W. B. Cannon, of Harvard University, piecing together the results of researches by Dr. T. R. Elliott and by himself on the action of the suprarenal glands, brought to light a very wonderful hormone mechanism—one which helps us in interpreting the action of growth-regulating hormones. When we are about to make a severe bodily effort it is necessary to flood our muscles with blood, so that they may have at their disposal the materials necessary for work—oxygen and blood sugar, the fuel of muscular engines. At the beginning of a muscular effort the suprarenal glands are set going by messages passing to them from the central nervous system; they throw a hormone—adrenalin—into the circulating blood, which has a double effect: adrenalin acts on the floodgates of the circulation so that the major supply of blood passes to the muscles. At the same time it so acts on the liver that the blood circulating through that great organ becomes laden with blood sugar. We here obtain a glimpse of the neat and effective manner in which hormones are utilized in the economy of the living body. From that glimpse we seem to obtain a clue to that remarkable disorder of growth in the human body known as acromegaly. It is a pathological manifestation of an adaptational mechanism with which we are all familiar. Nothing is better known to us than that our bodies respond to the burden they are made to bear. Our muscles increase in size and strength the more we use them; increase in the size of our muscles would be useless unless our bones also were strengthened to a corresponding degree. A greater blood supply is required to feed them, and hence the power of the heart has to be augmented; more oxygen is needed for their consumption and hence the lung capacity has to be increased; more fuel is required, hence the whole digestive and assimilative systems have to undergo a hypertrophy, including the apparatus of mastication. Such a power of coordinated response on the part of all the organs of the body to meet the needs of athletic training presupposes a coordinating mechanism. We have always regarded such a power of response as an inherent property of the living body, but, in the light of our growing knowledge, it is clear that we are here dealing with an hormonal mechanism, one in which the pituitary gland is primarily concerned. When we study the structural changes which take place in the first phase of acromegaly (see Keith, *Lancet*, ii, p. 993, 1911; i, p. 305, 1913) we find that not only are the bones enlarged and overgrown in a peculiar way, but also

the muscles, the heart, the lungs, the organs of digestion, particularly the jaws; hence the marked changes in the face for the form of the face is determined by the development of the upper and lower jaws. The rational interpretation of acromegaly is that it is a pathological disorder of the mechanism of adaptational response; in the healthy body the pituitary is throwing into the circulation just a sufficiency of a growth-regulating substance to sensitize muscles, bones, and other structures to give a normal response to the burden thrown on the body. But in acromegaly the body is so flooded with this substance that its tissues become hypersensitive and respond by overgrowth to efforts and movements of the slightest degree. It is not too much to expect, when we see how the body and features become transformed at the onset of acromegaly, that a fuller knowledge of these growth mechanisms will give us a clue to the principles of race differentiation.

There must be many other mechanisms regulated by hormones with which we are as yet totally unacquainted. I will cite only one instance—that concerned in regulating the temperature of the body. We know that the thyroid and also the suprarenal glands are concerned in this mechanism; they have also to do with the deposition and absorption of pigment in the skin, which must be part of the heat-regulating mechanism. It is along such a path of inquiry that we expect to discover a clue to the question of race color.

This is not the first occasion on which the doctrine of hormones has been applied to biological problems at the British Association. In his presidential address to the zoological section, at Sheffield, in 1910, Prof. G. C. Bourne applied the theory to the problems of evolution; its bearing was examined in more detail in an address to the same section by Prof. Arthur Dendy during the meeting at Portsmouth in 1911. At the meeting of the association, at Newcastle, in 1916, Prof. MacBride devoted part of his address to the morphogenetic bearings of hormones. Very soon after Starling formulated the hormone theory, Dr. J. T. Cunningham applied it to explain the phenomena of heredity (*Proc. Zool. Soc., London*, p. 434, 1908). Nay, rightly conceived, Darwin's theory of pan-genesis is very much of the same character as the modern theory of hormones.

THE EXPLORATION OF MANCHURIA.¹

By Capt. ARTHUR DE C. SOWERBY, F. R. G. S., F. Z. S.

[With 4 plates.]

Manchuria, perhaps on account of its being the ancestral home of the last ruling dynasty of the great Chinese Empire, has long been a country of considerable interest to explorers from the west, though, owing to peculiar difficulties, not usually presented in the cases of other unknown parts of the world, its exploration has not been so thorough or so rapid as might have been expected.

The difficulties which barred alike the scientific and commercial explorer, and effectually kept out the greatest pioneer of all, the prospector, lay in the fact that the Manchu emperors in their rule over China tried to keep closed the doors of this the sacred home of their forbears against the inquisitive and grasping Europeans. And, all things considered, and from their own point of view, they had considerable reason on their side.

As regards Manchuria itself, their first experience with the white "barbarians" of the west occurred when the Russians in their march of conquest across Siberia came into contact with the outposts of the Manchu Empire on the Amur in the seventeenth century, and at once a struggle commenced between the emissaries of the two mighty empires for the possession of this valuable stretch of territory, which ended in the nineteenth century in the whole of the Amur and Ussuri regions coming under the sway of the Tsar of all the Russias.

Next the Manchu emperors found the white man knocking with no uncertain hand at the doors of their domain in the far south, so that it is not to be wondered at that they tried to keep Manchuria closed to these aliens. Nevertheless, the whites have persisted in their purpose, and, after forcing the doors, have during the past century succeeded in finding out much about the wonderful country of Manchuria.

Very early in what may be called the modern history of the country the great explorer and naturalist, Pallas, reached the Amur region. He was followed in turn by Radde and Schrenck, and all three have left invaluable records of their discoveries.

¹ Paper read at the meeting of the Royal Geographical Society, May 26, 1919. Reprinted by permission from the *Geographical Journal*, Vol. LIV, No. 2, August, 1919.

In 1886 three noted travelers, James, Younghusband, and Fulford, made their historic journey through Shenking (now known as Fengtien) and Kirin, to the sacred peak, Lao Pei Shan (Peiktusan), of the Chang Pei Shan range, and northward to the Sungari River and into Heilungkiang Province. The record of their journey was perpetuated by James in his standard work "The Long White Mountain."

Later still Sir Alexander Hesse made his journeys through the country and along the Amur, and he too has ably contributed to our knowledge of the country in his book "Manchuria, Its People, Resources, and Recent History." In addition to the records of these travelers and explorers there is a considerable amount of literature in Russian and Japanese, which, alas, is sealed to most Britishers and sadly curtails our general knowledge of the country. It is to be hoped that these records of good work done will some day appear in the English language, for it is hardly likely that either Russian or Japanese will ever become part of the curricula of our British schools and colleges.

While travelers and men of science have thus been busy, the representatives of the commercial world have not been idle, for the barriers set up have been broken down and trade relations established so that the southern and western parts of the country have become fairly well known to the outside world.

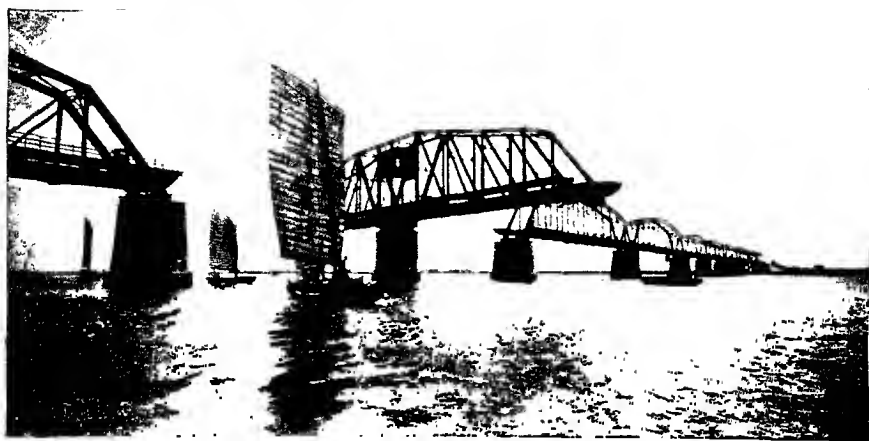
In the last few years, with increased facilities for travel, and with the passing of the old suspicions against outsiders, scientific men as well as traders and missionaries have penetrated the country to a considerably greater extent than was formerly possible. Even so, there still remain large tracts of unexplored country, while there is still much to be learned regarding its topography, fauna, flora, geology and mineral and economic resources; and it is with my own small share in the work of exploring these last stretches of unknown territory that I propose to deal to-night.

In preparing this paper it has been difficult to determine just what line to take; for, though in the course of the past 12 years I have done a certain amount of geographical exploration, notably in Shansi, Shensi, North Chihli, and Inner Mongolia, as a naturalist I have been concerned primarily with the fauna and to a lesser extent the flora and geology rather than with the geography of these districts.

Nevertheless, it is not easy for even the most casual traveler to pass through a country without gleaning some idea of its geography, topography, people, and products, and, as I hope I may claim to be something more than a casual traveler, I feel that, as one of the most recent scientific travelers in Manchuria, there may be some-



1. THE YALU NEAR ANTUNG.



2. RAILWAY BRIDGE AT ANTUNG ON THE YALU.



3. LOG RAFTS ON THE SUNGARI AT YEN-TUNG LA-TZÜ, NEAR MOUTH OF HUI-FA HO.



1. COREAN DUGOUT ON THE YALU.



2. CHINESE CRAFT ON THE YALU.



3. CRATER LAKE NEAR CH'AO-YANG CHÊN, KIRIN FOREST.



4. THE HUN KIANG, NEAR WAI-CH'Ä-KOU.

thing of interest regarding that country for me to lay before the members of this distinguished society.

As a field naturalist I have been working under the auspices of the United States National Museum, a Government establishment under the direction of the Smithsonian Institution. It has been my good fortune to make several excursions from my headquarters in Tientsin into Manchuria, a land of mighty rivers and great primeval forests, of volcanic hills and mountains and wide alluvial plains.

My first visit was made in the spring and early summer of 1913, when I entered Kirin Province, via Kaiyüan on the Moukden-Harbin Railway line, and, after a period spent in the forest to the southeast of Chaoyangchen, took boat and explored certain parts of the upper Sungari River and its tributaries, finally reaching the town of Kirin, or Chuanchang, and thence by river steamer and railway arriving back in Tientsin in August.

In the spring of the following year I made a journey by boat up the lower portion of the Yalu River and its tributary, the Hunkiang, taking the opportunity to visit Port Arthur and Dalny *en route*.

The following autumn and early winter were spent in the forested regions in northern Kirin Province, between Harbin and Ninguta.

In the summer of 1915 I traveled with a friend to Harbin, and thence down the Sungari River as far as its junction with the Amur. It was found impossible, however, to continue in this direction, owing to the suspicion and inimicability of the Russian authorities, so we turned back and spent the autumn once more in the forests of northern Kirin.

Had I been on a purely geographical quest my wanderings would undoubtedly have been of a far wider scope, but it will be readily understood that the search for small mammals, birds, reptiles, and even larger quarry, depends for its success rather upon getting to know one more or less limited area well than in making lengthy and rapid traverses of wide stretches of country. The several excursions just mentioned were undertaken with a view to tapping typical areas in Manchuria, and certainly the results they yielded were highly satisfactory, though it must be stated at once that little in the way of absolutely new species was discovered.

Before going into details of my own travels, it might be as well to take a rapid survey of the geography, configuration, communications, and resources of Manchuria as they exist to-day, for since James and his party and Hosie made their extended journeys in that country considerable changes have taken place. The settling up of the wilderness by Chinese has continued on an ever-increasing scale; railways, undreamed of then, have come into existence; the great rivers of the north have been supplied with steamboat services; and

vast areas of forest have been transformed into smiling farm lands. The few aborigines have become further reduced, while foreign influence—Russian, Japanese, and Chinese—has greatly increased.

The three Provinces of Manchuria—Fengtien, Kirin, and Heilungkiang—occupy a broad horseshoe-shaped belt of country, of which the outer (eastern) edge is bounded by four great rivers, the Yalu and Tumen, on the south, forming the boundary between Fengtien and Kirin and Korea; the Ussuri, on the east, dividing Kirin from the east Siberian Province of Primorskaya; and the Amur, or Heilungkiang, on the north, separating Heilungkiang Province from the Amur Province, or Amurland. Formerly, during the Ch'ing dynasty and right into the nineteenth century, both Amurland and Primorskaya belonged to Manchuria, and to this day the aborigines of these great stretches of country should be considered as Manchurians rather than Siberians.

The western boundaries of Manchuria are less clearly defined, though here the Provinces come into contact with eastern Mongolia. The more or less arid steppes of which the latter country is formed do not end with the political boundary line, but extend beyond the border into the more fertile terrain of Manchuria. Thus portions of northern Fengtien, western Kirin, and southwestern Heilungkiang are more typical of Mongolia, and we find the aborigines pertaining to the more truly Mongol race, such as the Daurians.

Of the three Provinces, Fengtien has been longest under cultivation, and has figured the most in the history of China, Mongolia, Manchuria, and Korea. It consists of rather bare, rocky hills and mountains in the west and southeast, with a wide flat plain between, which runs in a northeast southwest direction, joining up with the east Mongolian steppes in the north, and bordering the Liao-tung Gulf in the south. Down this plain flows the Liao River, and on it are situated many important towns, such as Chinchowfu, Moukden, Tiehling, and Kaiyüan. The Peking-Moukden Railway traverses it from Shanhaikwan to Moukden. A branch line from Kowpantze runs to Yingkow at the mouth of the Liao River. From Moukden run three branches of the South Manchuria Railway. One strikes southwest and runs as far as Port Arthur and Dalny (Dairen), on the Liaotung Peninsula, with a short branch to Yingkow. Another running southeast reaches Antung at the mouth of the Yalu River, which it crosses by means of a magnificent steel bridge, and is continued in Korea as the Chosen Railway. A third, which is really a continuation of the first, runs north to Changchun, where it makes connection with the Changchun-Kirin Railway, and a branch of the Chinese Eastern Railway which runs south from Harbin. The main line of the Chinese Eastern Railway runs from Vladivostok to Man-

chouli through Ninguta, Harbin and Hailar. The Liao River is not navigable except for light-draft native boats, but of this type of craft it carries a considerable number.

Fengtien is given almost entirely to cultivation, maize, wheat, sorghum, millet, beans, and, of late years, rice being the main cereals grown. A considerable amount of tobacco is grown, while silk is extensively cultivated in the hills of the south and southeast, the silk-

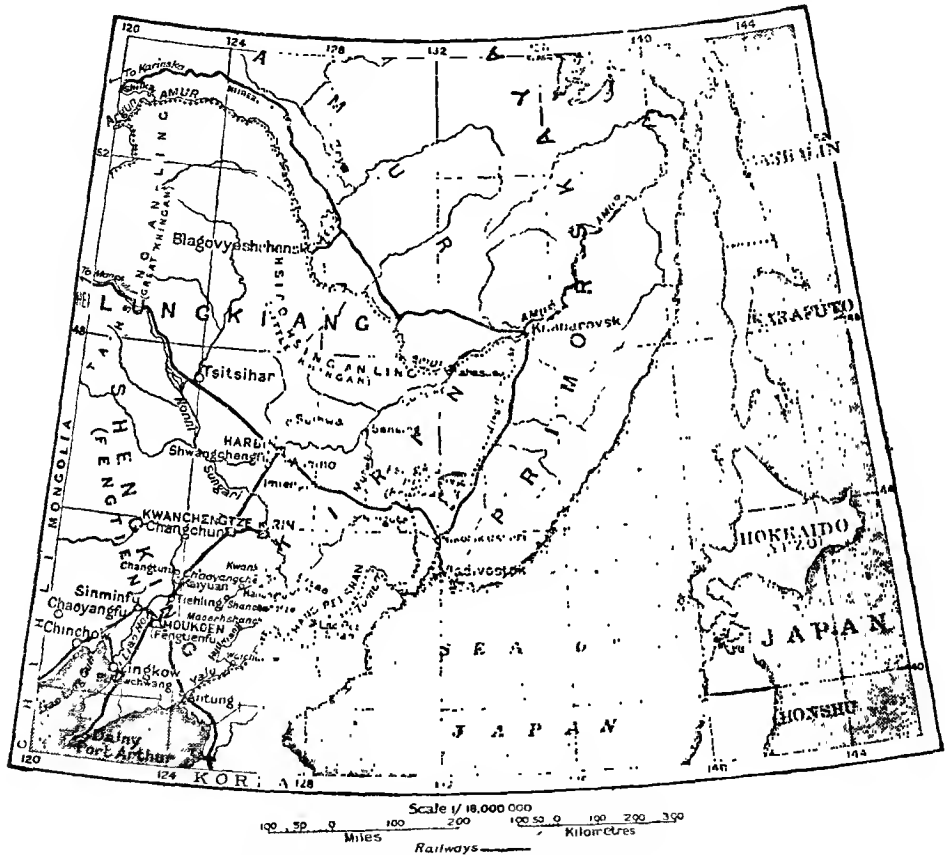


FIG. 1.—Sketch map of Manchuria, prepared from the Manchuria sheet of the 1/5 M Asia

worms being fed on scrub oak specially grown for the purpose. The raw silk is extensively exported to Shantung, where it is manufactured into the famous pongee. All attempts to induce the silk weavers of Shantung to settle in Manchuria have failed.

The Japanese Government has had schemes for inducing her own nationals to settle on land along the railway lines controlled by her; but this also has proved a failure, probably owing to the inability of the Japanese peasants to compete favorably with the local Chinese farmers.

To the east of Fengtien lies the beautiful and fertile Province of Kirin, or Chi Lin, meaning "clear forest." At least a third as large again as Fengtien, this Province supports at present a far smaller population, though it is being settled up rapidly.

The great Kirin Forest, which stretches from a little north of the Yalu up the middle and west of the Province, in places to the very banks of the Sungari River, east of Harbin, and well into the angle formed by the junction of the Ussuri with the Amur, has been estimated as covering an area equal to that of Scotland. The whole of the Chang Pei Shan Range is heavily forested, though this area is being exploited for its timber by the Japanese on the southern and the Chinese on the northern slopes of the range, the former getting the timber out by the Yalu, and the latter by the Sungari and its tributaries. Farther north in the Province, between Harbin and Ninguta, the forest is being tapped by Russian and Chinese companies, the timber extracted consisting chiefly of pine. It is transported from the forest by the Chinese Eastern Railway, and most of it goes to Vladivostok, whence in pre-war times it found its way to Europe. An enormous quantity of oak, walnut, and maple is also cut to supply fuel for the population, the locomotives, and the steamers that ply on the Sungari. The forest in the northeast of the Province consists mainly of deciduous trees, chiefly oak.

Besides the Chang Pei Shan Range in the south, the center and eastern portions of the Province are occupied by high hills and even mountains of plutonic and volcanic origin.

The Province is drained by the Sungari River, the Mutan Ho (Peone River), and the left tributaries of the Ussuri River. The Sungari is navigable for native boats for about 100 miles above (i. e. southeast of) Kirin City, and by steamers from its mouth to that city. The Mutan Ho carries boat traffic at least as far as Ninguta.

The western section of the Province and the valleys of the large rivers and their tributaries are now under cultivation, while settlers are steadily pushing farther and farther up the valleys, thus opening up the country. With the exception of rice and silk, which are not grown, the products of cultivation are the same as those of Fengtien.

The Province of Heilungkiang, which means the "black dragon river," is by far the largest of the three. It contains two extensive mountain systems, the Little Khingan Mountains in the southeast and the Great Khingan Mountains in the west. These mountains are for the most part heavily forested, and have been barely touched by the explorer.

The Nonni Ho, an important tributary of the Sungari, drains the eastern portion of the Province, the western portion being drained by the Argun and Shilka, tributaries of the Amur.

The Province is bounded on the north by the Amur, and on the south by the Sungari. It has practically no railways, the western section of the Chinese Eastern Railway only passing through the southwestern corner. However, the Russians have recently built a railway down the left bank of the Amur from Karimskaya, near Chita, to connect up with the recently opened Ussuri Railway at Khabarovsk, while steamers ply on the Amur at least from Blagovyeschensk² (noted for a brutal massacre of Chinese by the Russians, who some 15 years ago³ drove the Chinese inhabitants, consisting of some 2,000 souls, at the point of the bayonet into the river) to its mouth, and up the Sungari as far as Harbin and even to Kirin.

Of the state of cultivation and the products of this Province I can not speak at first hand, except to say that along the banks of the Sungari the rich soil is rapidly being brought under the plow for the production of the soya bean and other cereals. The fur-hunting and fishing industries are also of great importance.

As already stated, I made four expeditions from Tientsin into Manchuria. The first of these had for its object the exploration of the forested area of western Kirin. After reaching Kaiyüan by train, my companion, Major Bowker, and I engaged carts and proceeded eastward to a place called Chaoyangchen, which is situated within 10 or 15 miles of the outskirts of the forest, close to the Fengtien-Kirin border. We passed a number of villages on the way, and two rather large towns, Shanchengtze and Hailungfu. These were new and, from all accounts, of mushroom growth. Indeed, the road we traversed led through country that showed abundant evidence of having come under the plow but recently.

From Chaoyangchen, where we stayed a couple of days with Dr. and Mrs. W. Young, of the United Free Church of Scotland Mission, we set out in a southeasterly direction, and, after passing the new township of Huinanting, where the local official did his best to stop our further progress, owing to the fear that we might fall foul of a notorious band of Hung-hu-tzu (bandits) that infested the neighboring forest, we entered and traveled up the valley of the Hama Ho (Frog River). We were very soon in the forest, which here consisted mainly of oak, walnut, elm, and maple, the first three mostly of gigantic size. There had been conifers—pines and spruce—but these had been cut away by recent settlers, who were everywhere making large clearings, building log cabins, and cultivating the rich soil.

The roads, if one may use the term, were excessively bad, and we had considerable difficulty in making headway. We had not gone

² As a matter of fact, they run up as far as Stretensk on the Shilka River. A. deC. S.

³ This massacre took place in 1900, during the Boxer outbreak.

far when one cart was overturned into a deep pool beside the road and its whole contents soaked. At one place we had to cross a treacherous "niggerhead" swamp. A niggerhead swamp is one in which the soft, black ooze is closely dotted with peculiar tussocks of grass. In summer the long grass hides everything, with the result that in trying to cross the swamp one encounters a series of pitfalls as one's feet miss the tussocks and plunge one into the ooze, often up to the waist. In the autumn or spring, when fire has consumed the long grass, as it often does, the tussocks look like so many black heads covered with fuzzy black hair, whence the name "niggerhead." The difficulty of getting a heavy cart across such a swamp can be imagined. Add to this a soaking, steady rain and it will be understood that our plight was far from pleasant. However, by the end of the second day we had managed to penetrate the forest sufficiently far for my purpose of making a typical collection of small mammals, so camp was pitched in a suitable spot, and I lost no time in getting my traps out.

It was a wonderful place we had chosen. A beautiful stream flowed near by, whence the natives daily brought us fresh trout and grayling. Big, fat pintail snipe were abundant on the open swamps and recent clearings, while hazel grouse and pheasants could be heard, though seldom seen, in the forest itself. Many bright-plumaged birds were seen, most noteworthy of which was the beautiful oriental roller (*Eurystomus calonyx*, Sharpe), with its brilliant blue and green plumage, crimson bill and legs. There were a great many of these birds about, but they kept to the tops of the highest trees and defied all our efforts to secure specimens, while they disported themselves in the air and uttered incessantly their shrill chattering calls. Jays, cuckoos, woodpeckers (pied and black), warblers, flycatchers, finches, hawks, owls, herons, kingfishers, and grebes were all seen and noted.

Small mammals were scarce, however, so we decided to push on farther up the valley. We finally reached its head after another day's travel, where a friendly settler, practically the last in this direction, gave us shelter in his log-built huts. Here an interesting discovery was made. We had heard rumors of a wonderful lake, called by the natives Laolungwan, and had determined to visit it. Having, therefore, made ourselves comfortable at the farm, we lost no time in making for the lake, which lay but a mile or so away. A steep ascent up the head of the valley brought us to the object of our search, and there, like an emerald set in gold, lay the most beautiful lake it has been my fortune to see. It did not take long to determine the fact that this wonderful sheet of crystal clear water occupied the crater of an extinct volcano. In the course of my stay in this vicinity I visited another similar lake, while the native hunters told me that

scattered through the forest to the east and south was a series of 72 such Lung Wan (dragon pits), of which half were dry and half contained lakes, and that they all had their origin in one big mother lake far away to the east. Apparently, then, we have here a series of extinct volcanoes, doubtless belonging to the same system as that of the Chang Pei Shan, the culminating peak of which, the Lao Pei Shan (Paiktusan), visited for the first time by James and his party in 1886, is itself an extinct volcano with a lake in its crater similar to the one we visited.

While ascending the valley of the Hama Ho I had frequently noticed outcrops of volcanic slag and lava, and subsequently, while traveling from this locality, found that the rock formation of the whole country to the north was of volcanic origin, a thick layer of columnar basalt lying upon a granitic massif.

After wandering about in the forest for a couple of days in search of wild pig or bear, without success, my companion decided to return to civilization; but, as I was still far from satisfied with the results of my trapping and hunting, I stayed on. There was a band of Hung-hu-tzu in the vicinity that was continually on the prowl, and to this day it is a puzzle to me how I did not fall foul of them in my frequent long tramps through the forest. I had a guard of 14 foot and 2 mounted soldiers with me, but these brave warriors kept to the farm and refused point-blank to accompany me on any of my excursions. At last word was brought in from a neighboring homestead that the bandits had increased their number to 30, all armed with modern rifles, and that their leader had been making tender inquiries about the European staying at Liu's farm. On the arrival of this news I received a deputation from my guard, accompanied by my host, Mr. Liu, and a little Shantung hunter I had engaged, who begged me to leave the place and return to Chaoyangchen, since, were I to come to any harm, they would be held responsible by the official at Huinanting. There seemed nothing left to do but to evacuate; but to show my independence I stayed on a couple of days while I gathered in my long line of traps, finally packing up my gear and returning to Chaoyangchen.

Here I bought a small native boat, and with my two servants and the late owner of the boat as crew and a small black bear cub as supercargo, I sailed down the Huifa Ho to its junction with the Sungari River.

Various adventures in the way of shooting rapids and getting stuck on sand banks kept the journey from becoming dull. Indeed, the second rapid we descended so frightened the boatman that he ran away that night, and I had to engage another old riverman to assist in handling the boat. Once, through mistaking the opening in a fish boom that stretched across the river, we sailed bang into it. The boat

keeled over and would have capsized but for the fact that the whole boom gave way and we righted ship and raced on before the wind to the accompaniment of loud curses from the fishermen on the shore. It was their fault, however, for they had failed to mark the opening in the boom with the customary red flags.

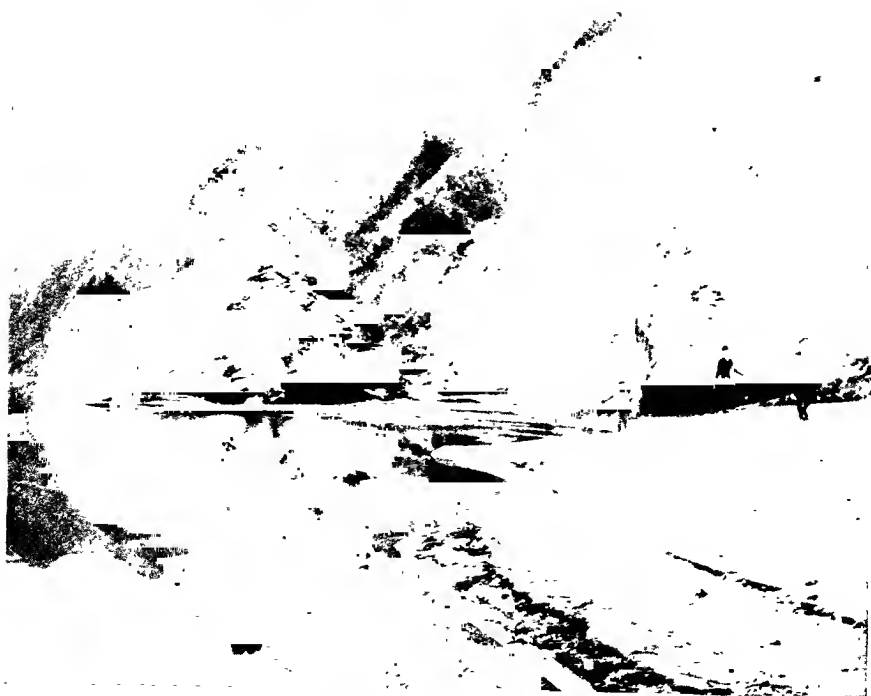
At the mouth of the Huifa Ho we turned southward and with considerable toil towed the boat a few miles up the Sungari till we came to likely looking collecting grounds. Then, crossing the river and choosing a good site on high ground, we pitched camp once more. I was very successful at this place and spent a month there. Besides small mammals, of which a large and interesting collection was made, numerous specimens of beetles and reptiles were taken at this point, while I was able to note and study the bird life that abounded in the vicinity. Botanically, too, the spot was ideal, for not only were there wooded areas, but there were also rocky cliffs, open uplands, wide clear valleys and marshes, all within easy walk of my camping site.

It was while camped here that I was able to form some idea of the amount of timber that is being cut on the slopes at the sources of the Sungari and its tributaries. Every hour of the day dozens of huge rafts of logs came floating past. Some of these contained twenty or thirty thousand feet of timber, averaging 3 to 4 feet in diameter, sometimes much more. This timber, I was informed, was cut and hauled to the water's edge during the winter by native woodcutters, who were engaged by timber merchants and their foremen. It was a very profitable business, the timber realizing a good price at Kirin City. They told me that there were still unlimited supplies of timber on the slopes of the Chang Pei Shan.

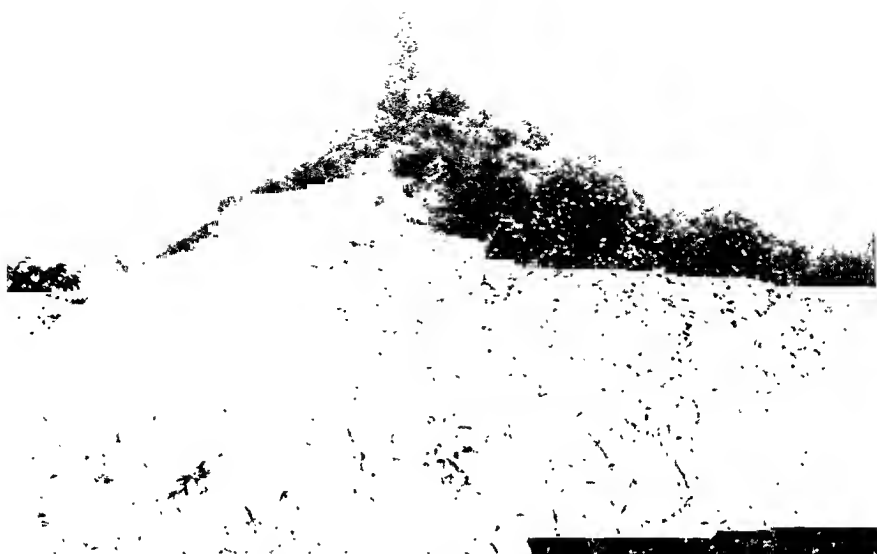
At last, having come to the end of my supplies, I decided to return to civilization and one morning put off in my little boat and commenced the journey down the Sungari in a fog. It was well for us that it was foggy that morning, for in it we were able to slip past a band of Hung-hu-tzu that were lying in wait for me at the mouth of the Huifa Ho. I should have known nothing about this but for the fact that a few nights before I woke up to find a man in my tent. By covering him with my revolver and calling my cook up from the next tent I made him prisoner. We then found he was armed with a long knife, and on his own confession he informed us that he was after my rifles so that he could join a band of Hung-hu-tzu across the river. Further inquiries of farmers across the river elicited the fact that this band of robbers were hanging around to hold me up whenever I should start down the river. As a matter of fact, a few days later a missionary and his wife, who were traveling by river from Chaoyangchen to Kirin, were held up by this same band and robbed of all they had.



1. CHINESE RIVER CRAFT ON THE SUNGARI RIVER, MANCHURIA.



2. ON THE YALU, 50 MILES FROM ANTUNG.



1. CHIMNEY ROCK AT YEN-TUNG-LA-TZÜ, SUNGARI RIVER, NEAR MOUTH OF HUI-FA HO.



2. COLUMNAR BASALT ON GRANITIC MASSIF, UPPER YALU, 60 MILES SOUTHEAST OF KIRIN

Without any further untoward event, and, except for the shooting of a dangerous rapid called Shiaoagno Ho, without excitement, the journey was accomplished in three days. At Kirin I gave the boat to the old boatman, thereby earning his eternal gratitude, boarded a paddle-wheel steamer, and reaching the railway line between Harbin and Changchun at the point where it crosses the Sungari, caught the southbound train, and was back in Tientsin once more within 48 hours.

The journey up the Yalu River the following spring was one of intense interest. Moreover, it yielded very pleasing results in the way of collections of mammals, birds, fishes, reptiles, batrachians, and insects; was, in fact, one of my most successful expeditions into these regions. Having taken steamer from Tientsin to Antung, via Port Arthur and Dalny (Dairen), I solved the problem of transport up the Yalu by engaging a roomy Chinese sampan, in which my always bulky baggage was comfortably stowed, allowing me room to sleep and live as well. It was a most delightful journey and, but for rapids, up which the sampan had to be pulled, was accomplished without any great labor.

It was disappointing, however, that, owing to the low state of the water and the dangerous nature of the rapids, we could not ascend the river farther than the town of Waichakow, about a hundred miles from its mouth. This decided me to turn up a tributary named Hun Kiang, and ascending its course till we came to suitable collecting grounds, I pitched camp and explored the neighboring country. The spot that I had chosen was simply alive with all kind of birds, reptiles, and insects, though, strangely enough, mammals were very scarce.

Later, in descending the main river, I stopped twice en route and made good collections of such mammals as occurred in the country from both banks. I found the Korean bank more wooded than the Manchurian, which I put down to the influence of the Japanese, who look after the timber more than the Chinese, besides enforcing useful game laws. Particular attention was paid to the fish of the Yalu, with the result that a good and typical collection was made.

The Korean population, so different from the Chinese, formed a never-ending source of interest. Particularly did their river craft attract one's attention. Excellent watermen when it comes to the use of canoes and paddles, the Koreans can not approach the Chinese as sailors. Their primitive devices for catching the wind to assist the progress of their dugout canoes and boats were ludicrous when compared with the well-made, well-handled and expansive sails used by the Chinese. The strange thing is that, though living side by side with the Chinese, and with such splendid examples of river craft before

them, the Koreans stick to their primitive dugouts, paddles, and pocket-handkerchief sails.

Taking them altogether, the Koreans appear to be a poor, listless, lazy people, content to live under the heavy hand of their Japanese rulers, so long as their long-stemmed pipes do not lack tobacco and their flasks the crude, raw spirits which they secure from the Chinese, and of which they are inordinately fond. The women, so far as one could judge, do all or most of the hard work, the men at the best indulging only in fishing, at which, by the way, they are past masters. It may be stated here that as fishermen, hunters, and even as agriculturalists the Koreans have spread into parts of Fengtien, right through Kirin, and may even be met with on the lower reaches of the Sungari, and it is remarkable how, wherever they go, they stick to their own dress, dugout canoes, methods of fishing, and manner of living.

The trips into the forest of Northern Kirin were carried out in the late autumn with the object of securing specimens of the larger mammals of the country. I had heard that the town of Imienpo, on the Harbin-Ninguta section of the Chinese Eastern Railway, was a good place to make one's headquarters while hunting in this region. This turned out to be correct, and during the months of September, October, and part of November, 1914, I made several excursions into the forests along the line, returning whenever my supplies ran out and revictualing at this little township.

Owing to the lack of transport and the nature of the forest in this district, it was impossible to make journeys of long duration. Instead, with two or three local Russian hunters, my servant and I, carrying on our backs only the barest necessities, would sally forth for three or four days at a time, shoot and trap what we could, and return with the skins to quarters reserved in Imienpo, where we would attend to their preservation.

This method, though arduous and hardly likely to produce the best results, served fairly well. Thus on the first trip two good specimens of the Manchurian wapiti were secured, as well as a roedeer, some birds, and a good series of small rodents.

Subsequently I tried hard to secure a wapiti with a good pair of antlers, but, though I traversed long distances and put up with considerable hardship, fortune was against me, and finally I was driven back to headquarters with a severe attack of rheumatism.

We next tried the country to the north of Imienpo and were rewarded by securing three bears and a couple of gorals, as well as a specimen of a black forest hare, some squirrels, minks, voles, rats, and mice, and some interesting birds. One of the bears was a fine specimen of what may be considered the Manchurian representative of the American grizzly. The animal measured seven feet in the flesh

from tip to tip, and was estimated at something over 600 pounds in weight. It was not fat, and the natives told me that this species did not get fat till much later in the autumn. It was subsequently identified with Heude's *Ursus*⁴ *cavifrons*, and appears to form, with other related species, a connecting link between the prehistoric cave bears of Europe and the North American grizzlies. So far as I am aware, this specimen, which now lies in the Smithsonian Institution collection, is the only complete one existing in any museum, though a skull, on which Heude based his description, lies in the Zikawei Museum in Shanghai. The other two bears were specimens of the common black bear of Manchuria, usually referred to *Ursus*⁵ *tibetanus*, but really a distinct species described by Heude under the name of *U. ussuricus*.

The forest in this part was very fine, being composed of oak, pine, spruce, and walnut, all of large size, with a considerable sprinkling of various forms of maple, which in their fiery autumn foliage formed a riot of color hard to describe. Everywhere the undergrowth was formed of a tangle of wild vine, richly laden with clusters of dark, well-flavored grapes, interspersed with ferns and various small shrubs.

There was a plethora of edible fungi, of which the Chinese recognized some four or five varieties, and which they were gathering and drying for their own winter use or export. Throughout the whole region were many dead-fall traps of ingenious design, from which one argued that in the winter the country was the resort of fur trappers. Indeed, I learnt that sables, martins, ermines, minks, otters, and squirrels were annually caught in large numbers.

My last expedition into Manchuria had for its object the exploration of the territory along the Amur River, but, as already explained, this was found impossible owing to the attitude of the Russian authorities. Rifles, shotguns, and cameras were forbidden on the Amur, while every stranger was viewed with distrust and suspicion. The reason for this was that a considerable number of Austrian and German prisoners had escaped from the detention camps in the Amur Province and formed a menace to the local populace. Not only so, but it was known that passports were being forged by the Germans in Shanghai or Tientsin, by means of which their nationals were getting about as British or French subjects. Thus it will readily be understood that a naturalist with his rifle, ammunition, and camera, and other more mysterious implements would prove an object of deep suspicion. Under the circumstances, after having traveled down the Sungari almost to its junction with the Amur, and having made collections at one or two places on the Heilungkiang bank of the former,

⁴ Now superseded by the generic name *Spelaeus*, Brookes.

⁵ Now superseded by the generic name *Sciencarcos*, Heude.

I decided to abandon the project of exploring the Amur till a more suitable occasion, meanwhile returning to Harbin, and thence proceeding to Imienpo once more to put in another autumn in the forest of that district.

To show the attitude of the Russians at this time, it may be stated that hardly had my companion, an American, and I left Imienpo for a trip into the forest than we were arrested as spies and narrowly escaped confinement in Vladivostok, if not a quick and sudden demise with our backs to a brick wall. It was only through the good offices of a friendly engineer on the railway, who got into communication with our respective consuls in Harbin, that we were finally released.

While on the lower Sungari I had an opportunity of seeing and talking with some of those strange people, the Fishskin Tartars, descendants of the old aboriginal Tartar inhabitants of Manchuria. But a small remnant of this tribe now exists, living in small communities along the banks of the Sungari and Amur, and obtaining a precarious subsistence by fishing, hunting, and a very little cultivation of the soil. Their chief town, La-ha-su-su, where about 500 families exist, lies at the junction of the Sungari and Amur; but there are a number at Fuchinh sien, and, I was told, at the mouth of the Ussuri River and up some of the side streams. Those I saw had taken to Chinese dress, except for hunting coats and caps of deer-skin; but they could easily be distinguished from the Chinese.

Mention should be made of an attempt, which I believe is proving very successful, to clear and cultivate on a large scale the low-lying land on the north (Heilungkiang) bank of the Sungari, near Fuchinh sien. The scheme is under the management of Europeans, who have imported American machinery for the purpose. Up to the time of our visit floods and the ravages of insects and disease had seriously hindered successful operations; but by diking in an enormous area of swampy land, and with the use of powerful pumps, splendid results have at last been achieved and bountiful harvests secured. This is in the nature of pioneer work, but its success will doubtless lead to further enterprise in the same direction, and we may shortly see wide tracts of rich and highly fertile land brought under the steam plow in this part of the country. Manchuria lies in the track of the great wheat belt of the world, and as the forests are cleared away we shall see a steady development of wheat growing and a corresponding increase in prosperity of the whole country.

In regard to the clearing away of the timber, which is only a matter of time, it seems a great pity that so large a timber reserve as that of Heilungkiang Province, not to mention that of Kirin, should be exploited, as it is now, in so wasteful a manner. Then again one would like to put in a word for the fast diminishing game

birds and animals of the country. On both these scores some very careful and stringent legislation is urgently needed if the future welfare of the people that occupy Manchuria is to be considered.

Though as yet the mineral resources of Manchuria have not been thoroughly explored, there are ample signs that in this line the country is as wealthy as in other ways. Gold has been washed in the rivers for a considerable period; while coal mines and iron occur in the south. Other minerals known to occur in useful quantities are lead and copper. Slate also is quarried in some parts.

The early history of Manchuria is more or less shrouded in mystery, but from what has been handed down it would appear that this land of primeval forests was occupied by tribes of savages, who lived entirely by hunting and fishing. These early Manchurians (this term is not to be confused with Manchus) must have been closely allied to the North American Indians, or perhaps it would be better to say that they and the people who populated North America belonged to the same ethnic race.⁶ There is a striking resemblance noticeable even to-day between the North American Indians and the Gilyaks and Goldis of the Amur, Sungari, and Ussuri regions. The last, to whom belong the Fishskin Tartars, up to comparatively recent times, clothed themselves in the skins of animals and fish, the latter fact being responsible for the name "Yu-p'i-ta-tzu" given them by the Chinese.

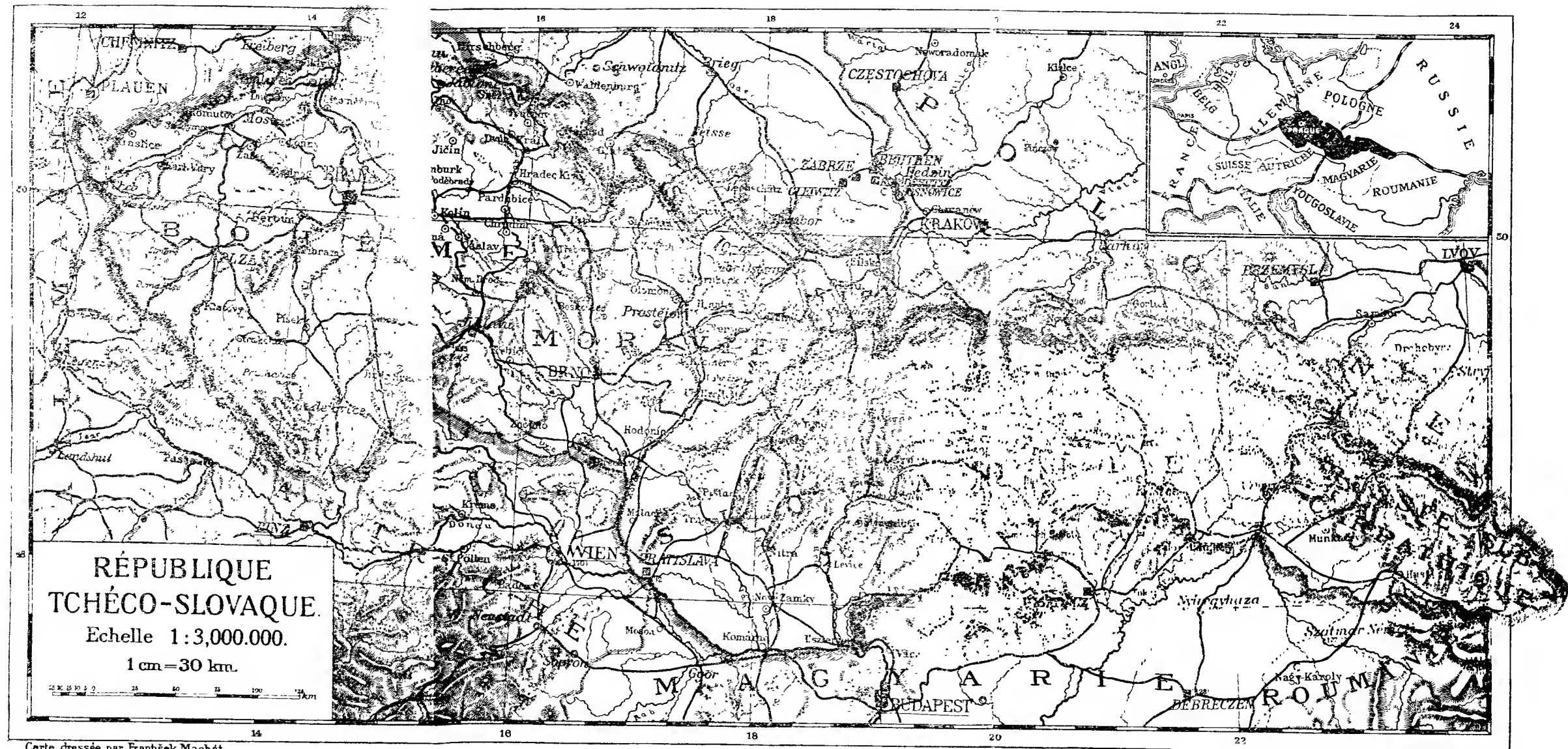
The early savages of Manchuria were continually engaged in inter-tribal warfare, which resulted from time to time in one or other of the tribes gaining the ascendancy and welding the others into a common State, sufficiently powerful to carry on successful warfare with neighboring highly civilized kingdoms. Thus China itself on more than one occasion was actually attacked and subdued, and Manchurian dynasties placed upon the throne. The last of these was the Manchu dynasty, or Ta Ch'ing (Great Clear), whose founder was the famous Narhurchu. Having established themselves in China, the Manchus practically deserted their own country, and except for the rich and fertile plains of the west that country must have slipped back into a more or less wild state, occupied by but a remnant of the old tribes. Then apparently began an immigration of Chinese, which has gone on steadily ever since, being accelerated in recent years by the wonderful opportunities the rich forest land and great river valleys have to offer the farmer and husbandman.

* * * * *

Though the civilization of the Chinese dates back to such antiquity, it is a great mistake to suppose that China is a decadent country, or

⁶ Dr. A. Hrdlička, "Remains in Eastern Asia of the Race That Peopled America," Smithsonian Miscellaneous Collections, vol. 60, No. 16.

its people a decadent race. In spite of periodical floods, famine, disease, and civil war, the population of China is, and has always been, on the increase. To-day many of the Provinces can not support this increase, and we have now, even as it was throughout the duration of the Ch'ing dynasty, a steady emigration of Chinese of all classes into Chinese Turkestan, southern Mongolia, and Manchuria. Now that the rigorous bureaucratic rule of Russia under the old régime has vanished, there is nothing to prevent Siberia being overrun, peacefully, by the Chinese settler and exploited by Chinese merchants, who can hold their own against any other people of these regions.



Carte dressée par František Machát.

FRONTISPIECE. THE CZECHOSLOVAK REPUBLIC.

Imprimée par V. Neubert, Prague-Smichov.

THE ORIGIN AND THE BEGINNINGS OF THE CZECHOSLOVAK PEOPLE.

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University, Prague.*

[With 4 plates.]

NOTE.

The notable history of old Bohemia, the recent liberation of the Czechoslovak people after three centuries of forcible subjection to Austria, and the wonderful anabasis of the Czechoslovak volunteer troops in Russia and Siberia, have raised in many minds a desire to know more about these people and their country. It is known that they are the western Slavs, but their exact derivation, their early history, the relation of the Czechs to the Slovaks, and of both to the other three main Slavic groups—the Poles, Russians, and Jugoslavs, together with their actual physical characteristics, are matters on which there was hitherto but scarce information. It was to supply authoritative information of this nature, based on scientific research of most recent years, that Professor Matiegka, one of the most competent and respected anthropologists of Europe, has published during the past year two brief treatises, one under the title of “The Bodily Characteristics of the Czech People” (8°, Prague, 1919), and the other on the “Origin and Beginnings of the Czechoslovak People” (8°, Prague, 1920). The present article is a partial abstract of the first with a part translation of the latter treatise.

The Czechoslovak Republic, as constituted after the peace conference, comprises the territories of Bohemia, Moravia, Slovakia, Subcarpathian Russia, and a portion of Silesia.

These territories cover nearly 55,000 square miles, and have approximately 14,000,000 inhabitants, of whom about 7,000,000 are Czechs, 2,800,000 Slovaks, and 450,000 Ruthenians. Besides these, there are about 3,000,000 Germans, descendants of the twelfth to nineteenth century immigrants, and about 1,000,000 Magyars, who in the course of their domination over Slovakia acquired domicile in that country.¹ The density of population is very great in Bohemia, reaching 210 per square mile (United States about 35, State of New York, including the city of New York, nearly 200 per square mile).

Bohemia lies in the heart of the European continent, the remaining Provinces extending below and partly into the Carpathians, towards the east. Bohemia itself forms a remarkable geographical unit. It is a great diamond-shaped

¹ The figures here given are merely estimates. The only official data are those of the 1910 Austrian and Hungarian censuses, which are grossly inaccurate as to the proportions of the different nationalities. The first census of the Republic is to be taken in February, 1921. See *La République Tchécoslovaque*, 8° Prague, 1920; *Statistical Handbook of the Czecho-Slovak Republic (in Boh.)*, 8°, Prague, 1920; and *Slovakia in the Light of Statistics (in Boh.)*, 8°, Prague, 1920.

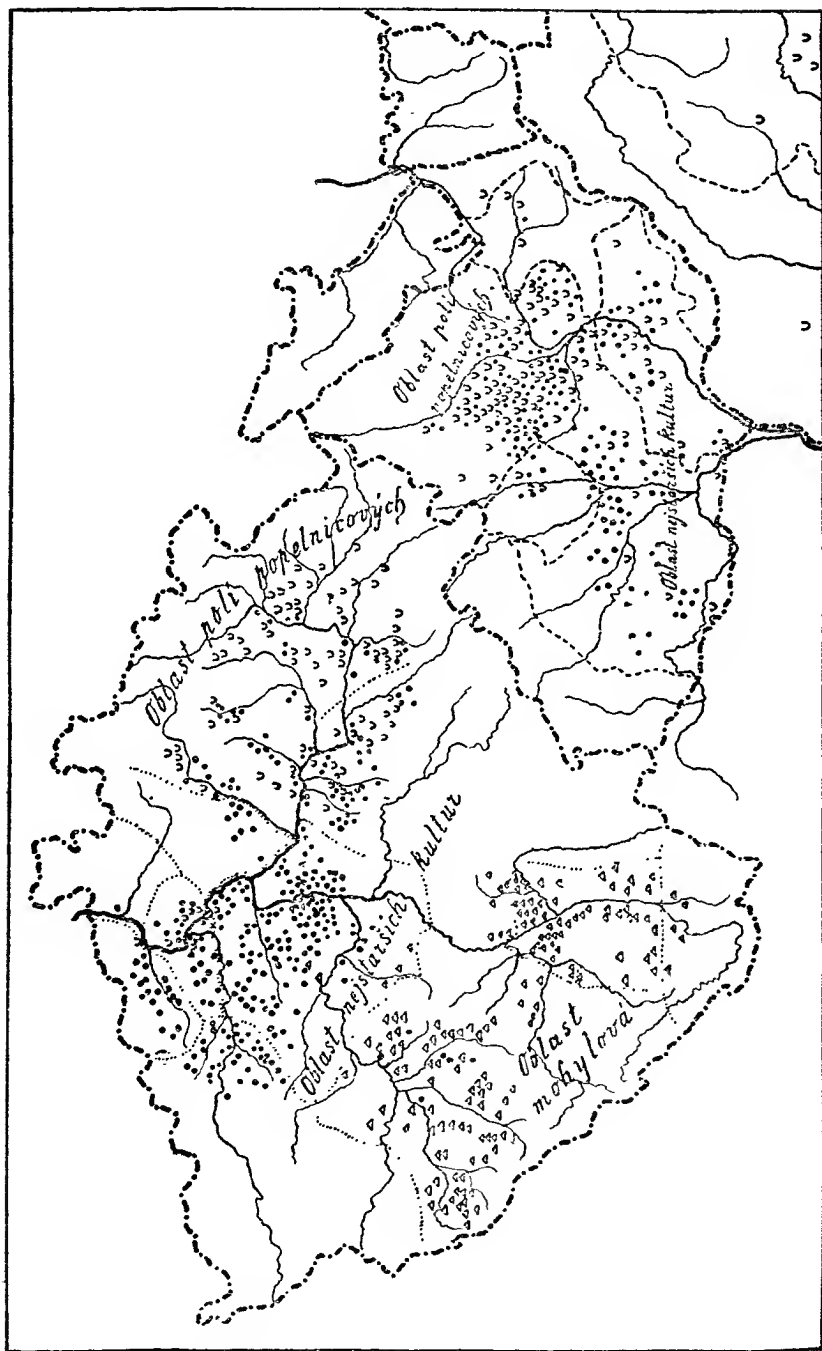


FIG. 1.—The peopling of Bohemia and Moravia in Prehistoric Times.

- Burials and sites of the oldest cultures.
- △ Mounds.
- u Urn-burials of Lusatian and Silesian Type.
- Later territories of Slavic tribes.
- Present dialectic boundaries.

amphitheater surrounded on all sides by mountains. Moravia, Slovakia, and Subcarpathian Russia, well protected by mountains in the north, are relatively open toward the south; but the western part of Slovakia is protected on this side by the Danube.

The territories are rich in natural resources, and Bohemia with Moravia are highly developed, developed in fact to the limit, agriculturally. Northern Slovakia and northeastern Russia abound in forests. Of the population of Bohemia 41 per cent are industrial, 32 per cent agricultural; in Moravia conditions are about reversed. The Slovaks and Russians are essentially agricultural and pastoral (61 per cent agricultural, 20 per cent industrial).

A. HRDLÍČKA.

ANTIQUITY OF MAN IN THE CZECHOSLOVAK TERRITORIES.

OLDER CULTURES OF CENTRAL BOHEMIA.

Various finds in the Czechoslovak territories relating to man's antiquity show that man existed in these countries already during the diluvial epoch, contemporaneously with the formation of the deposits of yellow brick clays and certain gravels and while the fauna still included the mammoth, the rhinoceros, the elk, the reindeer, the wild horse, the cave bear, and the cave hyena. The climate at that time was colder than at present, the period corresponding to the latest ice invasion, when most of northern Europe was covered with glaciers. The mountains surrounding Bohemia were then also covered with ice and snow, but in the foothills and in the ice free interior there were "stations" of diluvial man.

The most precious discoveries of remains of man from this period have been made in Moravia, in the vicinity of Brno (Brün), in caves near Štřamberk,² and especially at Předmost, where Professors Kříž and Maška made extensive excavations and important collections. Bohemia itself has given us so far the diluvial remains of Podbaba (a skull, etc.) and of a number of other localities. The finds include the bones of extinct mammals and many paleolithic implements. The art of polishing stone or of making pottery was as yet unknown. But finds in Bohemia itself have been thus far all slightly more recent than those of Moravia, dating from the period of recession of the last ice invasion. In Moravia, on the other hand, we have remnants not merely from the period of the last ice invasion itself, but also older, such for example as the Šipka lower jaw, and others.

An interesting feature of cranial remains from the more recent periods is that some of them retain more or less the characteristics of the older diluvial (Neanderthal) forms, such as pronounced supra-orbital ridges and sloping forehead, justifying the opinion

² NOTE.—Pronunciation of Czech letters: č č—as ch in child or cherry; š š—as sh in shoe or sherry; ž ž—as j in French jolle; ř ř=difficult sound, approached by combination of rz or rzh.

that early man in Europe, including the Czechoslovak territories, did not completely die out, but left traces in the later population.

These ancient strains represent the oldest, even though but a feeble root, of the people of these regions.

NEOLITHIC POPULATIONS.

If man in the Czechoslovak territories was scarce during the diluvial epoch, he was much more common there during the neolithic times. Meanwhile the climatic and environmental conditions had considerably changed; the diluvial fauna had become extinct; the reindeer receded to the far north. Man himself had advanced from the stage of a hunter to pastoral and agricultural life. His occupation now bound him to the soil, and we find his remains along rivers and other favorable locations both in Bohemia and Moravia, and even in parts farther east. Southernmost Bohemia, however, appears to have remained unsettled, which may be explained through its higher elevation, and hence colder climate with lesser fertility of soil, which characterizes this region to this day.

The remains of a large number of neolithic settlements in Bohemia and Moravia lead to the conclusion that the earlier part of the neolithic period was of long duration in these countries. Its beginnings in the Czechoslovak territories may be placed at as far as 4000, possibly even 5000 to 6000 B. C.

The neolithic culture was distinguished by numerous and characteristic stone implements, various implements and tools of bone and horn, and especially by pottery. Some of the pottery was decorated in various ways, and its characteristics help us to subdivide the epoch into a number of secondary phases or periods. It is unknown whether the art of making pottery originated gradually in the later part of the diluvial epoch or whether it developed or was introduced into the territories in question during the neolithic times, but no pottery has hitherto been found except in connection with neolithic or later burials.

Curiously, we do not know as yet how the early neolithic population of Bohemia and its sister lands dealt with its dead, having thus far found no burials; but on the Rhine burials that may be attributed to a related stock have been discovered, and it was found that the people to whom they belonged were of the dolichocephalic type, which was widely prevalent in Europe in the neolithic period.

Approximately 2000 to 1500 B. C. there began to enter from various directions into what are now the Czechoslovak territories, outside influences, and with them came the first objects of metal—small copper axes and bronze jewelry. The culture changed, forming a large "transitional" period of a number of phases or localized

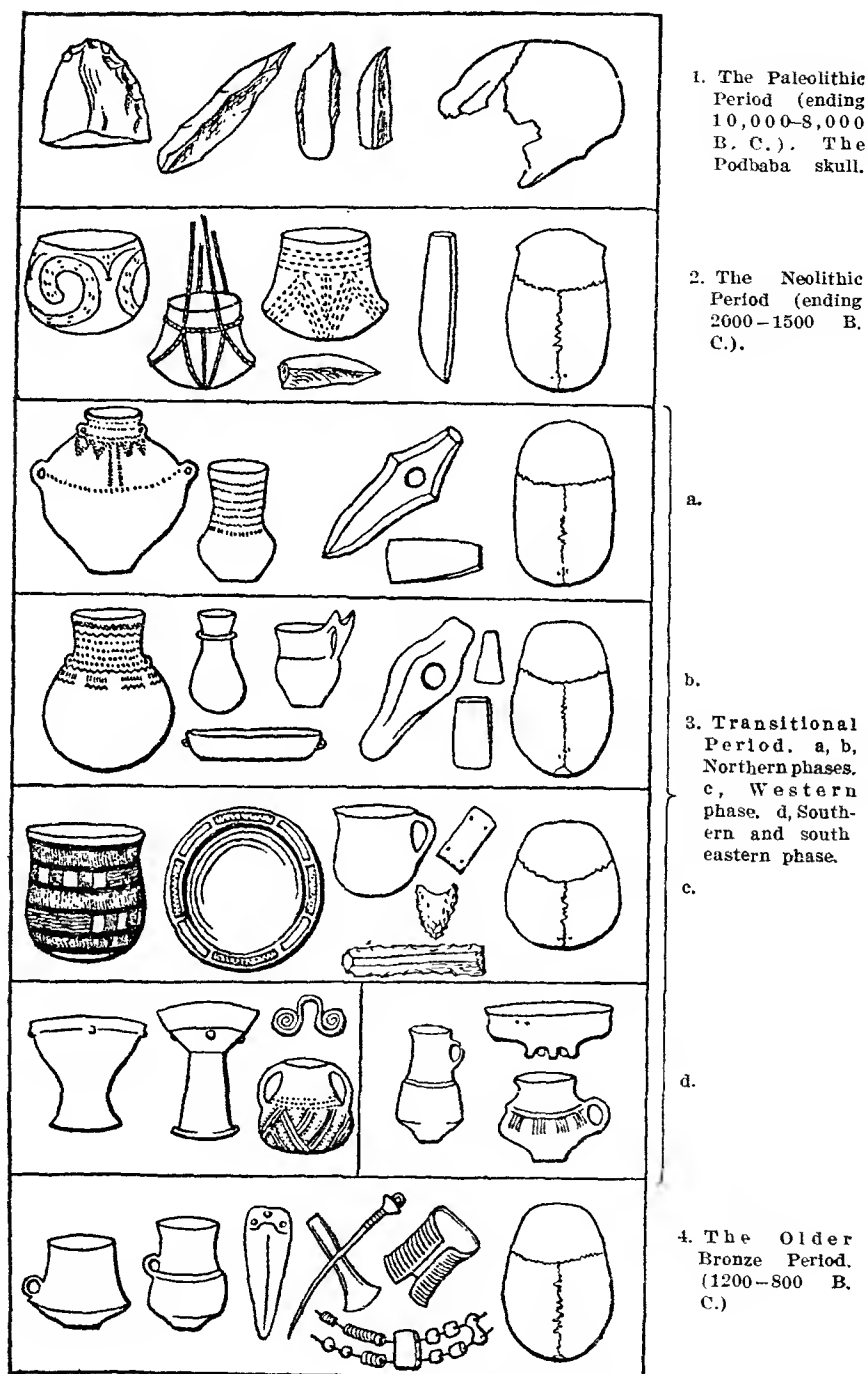


FIG. 2.—Characteristic objects and crania from the older cultures of the Czechoslovak Territories.

developments. The people of this period buried their dead in the contracted or "fetus-in-utero" position, with the body lying on its side. With the body were buried various mortuary offerings, particularly pottery. The multitude of objects known as a result from this period permits us to recognize the influence on the population of southwestern, western, northwestern, and northern, besides southern and southeastern cultures. There was evidently a very free contact with the outside world.

Besides cultural influences, however, there were also during this period actual influxes of other people. It has been found that skulls from burials showing objects of nordic culture are dolichocephalic, while those of burials showing a strong influence of western cultures are brachycephalic, in addition to which there were mixed elements. The population assumed a considerable heterogeneity. The prevalent cranial type was probably the dolichocephalic, but accompanied, there are some reasons to believe, not with blond but rather dark hair and eyes.

THE BRONZE CULTURE.

On the basis of the final "transitional" neolithic period and under the influence of additional contacts there next developed in the Czechoslovak territories, approximately about 1200 B. C., the "older bronze culture." The body was buried in the contracted position, was surrounded by stones, and with it were placed various forms of pottery, nicely shaped and with characteristic decorations. In addition there are also bronze armlets and pins, bronze or gold rings and earrings, amber-bead necklaces, characteristic bronze axes, and bronze daggers. Large burial grounds and a multitude of valuable burial offerings show that the people of this period lived in larger settlements, had trade relations with the north as well as the south of Europe and enjoyed considerable prosperity.

This older bronze culture, while extending beyond the borders of Bohemia, found its highest development in the center of that country. The skeletal remains from this period show people of higher stature, which may perhaps be explained by generally better living conditions. The skulls are prevalently oblong (dolichocephalic) and elliptical, with more or less marked parietal prominence. The population may be regarded in the main as the result of a fusion of the various ethnic elements of the transitional period.

THE MOUND CULTURE OF SOUTHWESTERN BOHEMIA.

The older bronze culture lasted according to the estimates of Czech archeologists up to the eighth century B. C. About that time the people of Bohemia became subject to the influence of two new outside ethnic elements which penetrated into the country, one from

the northeast and the other from the southwest, and which occupied parts of the territory. In southwestern Bohemia the new invasion gives rise to a special characteristic culture the remains of which are found in mounds (see figs. 2-5). The burial is generally on the level of the ground, is surrounded by stones, and covered by a moderate sized earth mound. Occasionally in addition the mound itself is surrounded by a ring of stones.

The older mounds yield objects of the advanced bronze period, such as bronze swords and other weapons, typical long bronze pins, armlets, etc.; but in later burials there begin to appear also objects of iron (knives, arrow points, etc.) and bronze objects characteristic of the younger bronze period. Finally, with the latest burials of this prolonged intrusive phase there are found objects of Roman derivation, such as coins and keys. The bodies of the mound builders were either cremated or buried as a whole; but even in the latter cases the bones, due to the construction of the graves, are generally in

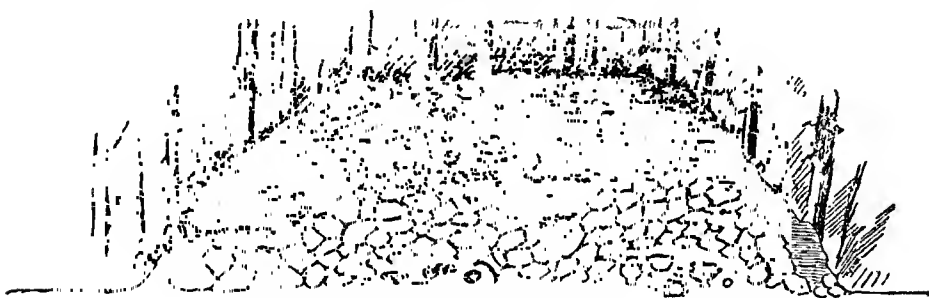


FIG. 3.—A section of a mound, showing two old burials covered by piles of stone, and an intrusive more superficial interment.

such poor preservation that it has not as yet been possible to form a precise opinion concerning the physical characteristics of the stock or tribe concerned. From the fact that mounds of this nature may be followed into Bavaria and farther on into Switzerland and France, we may judge that the physical type of the mound people in Bohemia resembled that of those regions, and there is some evidence to show that this was a dark-haired people, with rather a short skull. A gradual transition of the mound culture to the plain Slav culture in southern Bohemia (sixth to seventh century) indicates that the mound population was at least partly preserved and assimilated into the later Slav people.

ASH-URN CEMETERIES OF NORTHEASTERN BOHEMIA.

While or even before the mound culture began to spread over southwestern Bohemia, the northeastern part of the country began to be overspread by another and larger ethnic stream, which oc-

cupied first of all the sparsely peopled northeastern portions of the territory, but was soon overflowing across the more central regions, and which eventually, strengthened by new accretions, occupied all of Bohemia. The culture of this people is characterized in the first place by a special manner of disposing of the dead. The dead were cremated, the remains of the bones were deposited in urns, and these were interred in communal burial places which are commonly known as "urn fields" or ash-urn cemeteries. Besides the ashes and charred bones, however, there were placed in the urns also burial offerings, such as jewels and even weapons; while about the urns were placed

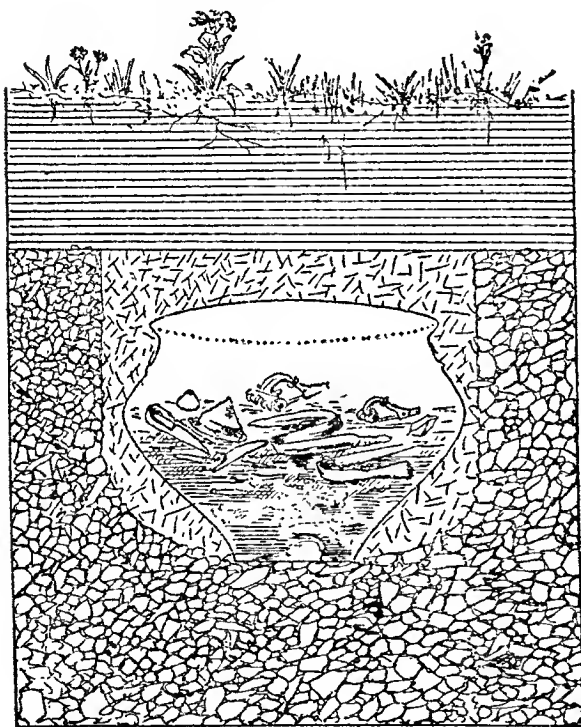


FIG. 4.—A cross-section of an urn burial on the Pič mountain, near Dobřichov.

other pieces of pottery, so that the burial occasionally resembles a nest of ceramics. The forms and decorations of the urns and offerings have their own characteristics, and with time show gradual changes, which permit us to classify this period into some secondary phases that can be traced upward directly to the early historical Slavonic time.

The influence of this new north-eastern culture extended over central Bohemia with-

out evidently displacing the older population, for there are instances where side by side with cremation we find also the surviving habit of contracted burial.

Due to universal cremation among these early Slav people, their physical type has not as yet been definitely determined; but some remains of bones indicate that they were of moderate stature and probably of light eyes and light brown hair, resembling the old Slav populations of Lusatia and Silesia, regions from which the influx occurred.

THE GALLIC (LA TÈNE) AND THE ROMAN PERIODS.

From the second century B. C. to the first century A. D., the central parts of Bohemia suffered a temporary invasion from the west by still another Gallic tribe, a physically strong and generally advanced stock, whose culture may be traced westward as far as the drainage areas of the Marne and Seine Rivers. They were evidently warlike people of Keltic derivation and their skeletal remains show prevalently a tall stature with mixed cranial type (about one-third brachycephalic). They were bearers of the La Tène culture, traces of which extend as far as Moravia, Poland, and even Slovakia. They formed settlements in Bohemia which were of some duration.

The La Tène culture in its latter phases begins to show contact with Roman culture, and toward the end the marks of such a contact are numerous. Finally there are even burials showing exclusively Roman culture, but found only singly and dispersed.

Notwithstanding these new influences, the Slav mode of cremation of the dead extended gradually over the entire country, displacing the other methods. The mortuary offerings of the first to sixth centuries show considerable development in metal objects with Roman influence. As cremation was then universal, we have no adequate data on the physical qualities of the people during this period, but there was doubtless a considerable diversity. During these times still other tribes entered Bohemia. One of these, to whom we ascribe the so-called "Merovingian burials," was evidently a Germanic tribe, while the others were additional Slavonic groups.

The Merovingian graves (sixth to seventh century, A. D.) are thinly dispersed over the northwestern districts of Bohemia, and it is possible that they belong essentially to Franc traders, with individual women who may have married into the country. The graves show extended skeletons with dolichocephalic skulls. The mortuary offerings include, besides characteristic pottery, iron weapons, glass beads, and in female graves considerable characteristic jewelry, with glass-bead necklaces, bone combs, etc. Contemporaneous with the Merovingian graves is an extension of Slavonic graves over all southern Bohemia.

HISTORIC PERIOD.

The above period passes directly into the historic Czech period, the period of the Bohemian dukes, and shortly after are noticeable the influences of Christianity. Cremation burials with mortuary offerings diminish, to be replaced by ordinary interments; but the extended bodies are still buried with the head toward the west and feet toward the east, as if to look toward the east. The grave is occasionally surrounded or covered by stones, later by posts or boards,

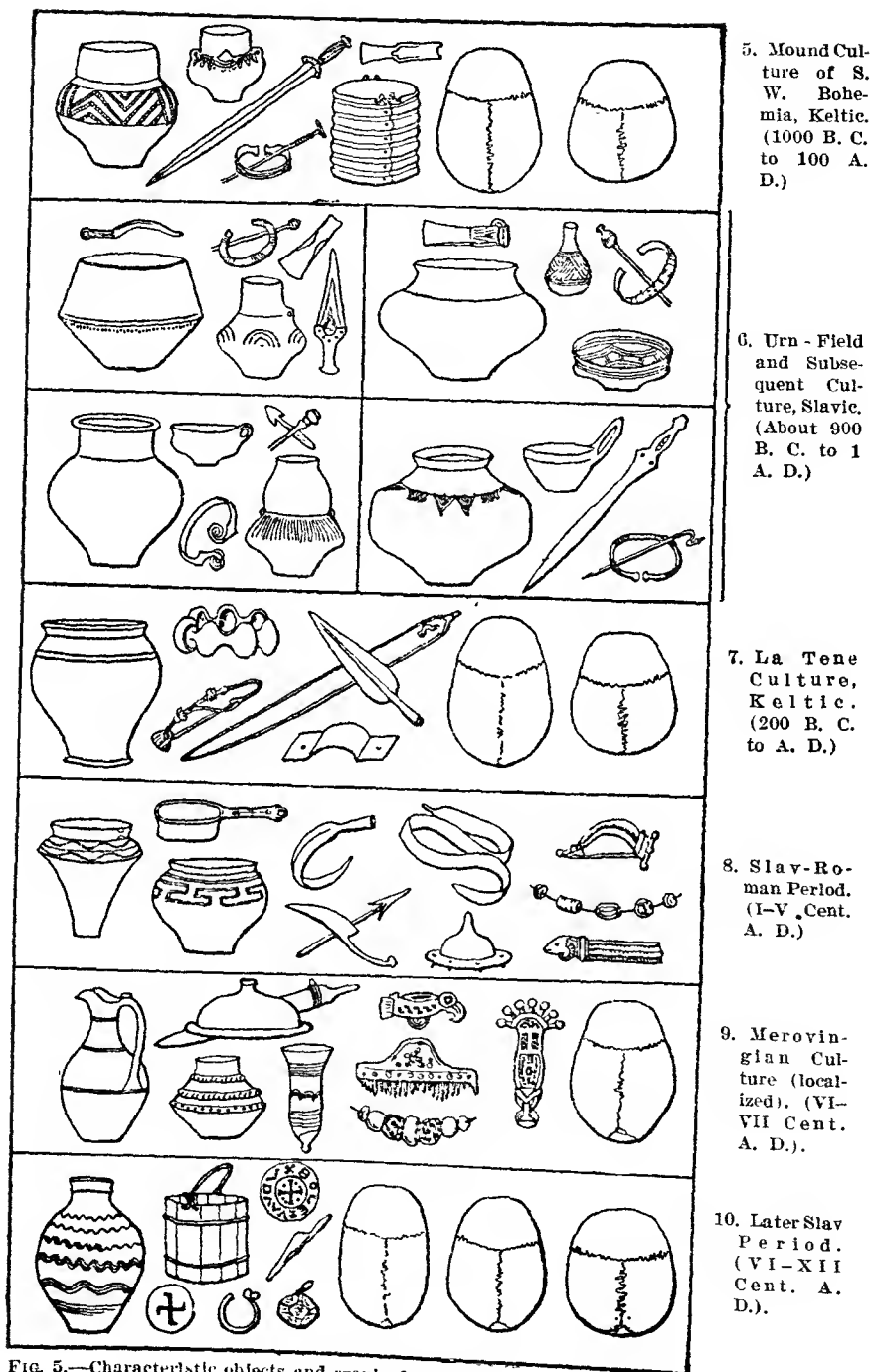


FIG. 5.—Characteristic objects and crania from the newer cultures of the Czechoslovak Territories.

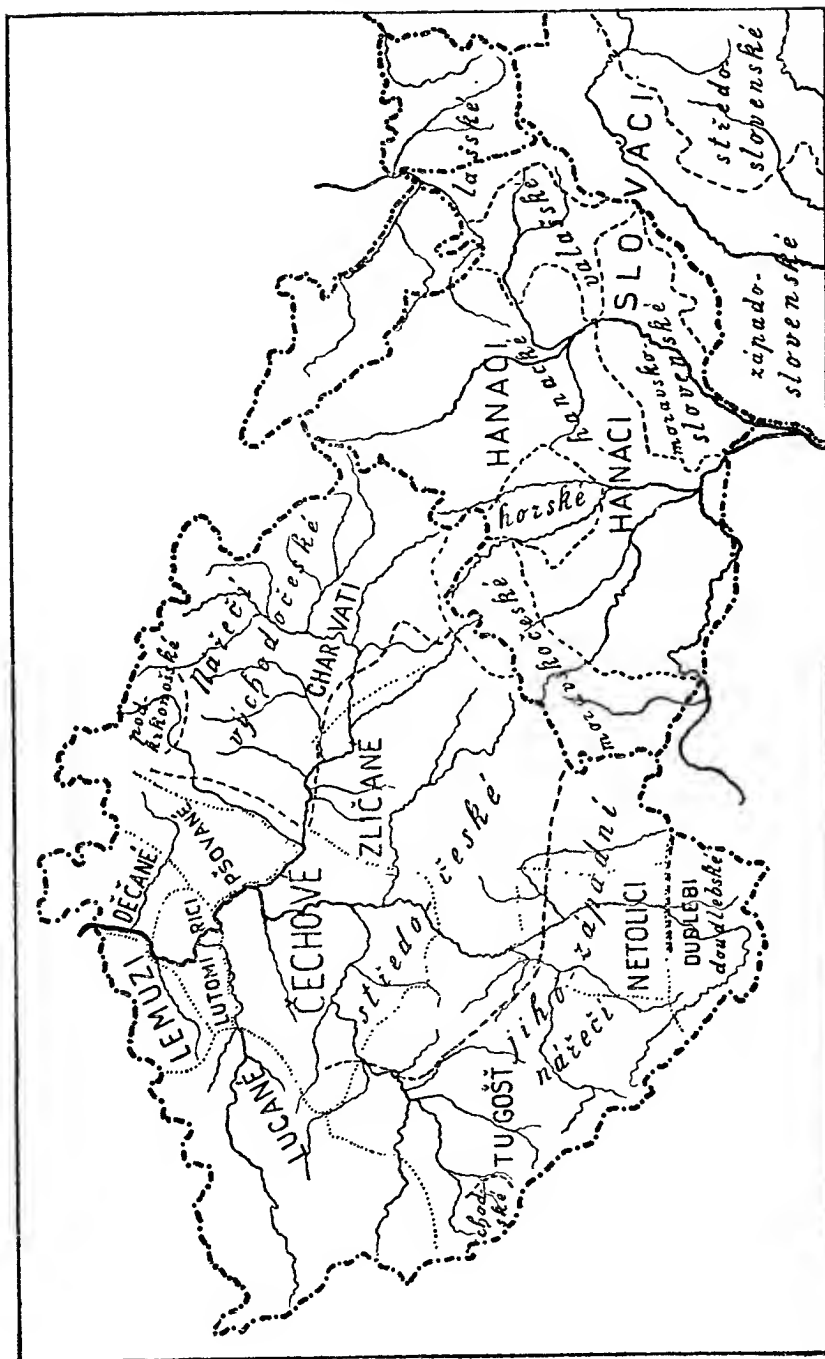


FIG. 6.—Areas showing the territories of the old Slav tribes of Bohemia and Moravia and in which the dialectic differences persist to this day.

and finally the dead were buried in simple quadrilateral wooden coffins. For a long time, however, the old customs were still manifested by the inclusion in the grave of clay or wooden vessels, evidently containers of food and drink for the last journey of the departed. In addition there is found, especially in female and children's graves, considerable jewelry, and eventually also Bohemian silver coins (tenth to twelfth century).

The reverence toward older burials of other peoples, the care shown in the burials of children and babies, the latter of whom frequently accompany the mother's body, and other signs are witnesses of the gentleness and advanced status of the people of this period.

The skeletons of this time show relatively high stature. The skulls, though already historically identified as Slavonic, are still in the majority of cases dolichocephalic or but mesocephalic, and only as we advance toward our period the proportion of short-headedness shows a material increase. In general the skeletal remains indicate that the Czech population of that time arose by the mixture of the more recently arrived with the remnants of the older peoples that occupied the territory. Then the Slav remains become suddenly so numerous and widespread that we are evidently confronted by recent new additions of Slavic tribes, among whom in all probability was also the tribe of "Czechs" from whom was derived the present name of the people as well as the country, "Čechy." The latest influx of Slavic tribes is placed by the historians into the fifth century and is still alive in Czech traditions, in which the name "Čech" is represented as that of the "father" or chief of the tribe at the time of their advent into the more central part of Bohemia, which has ever since remained their seat of occupation.

THE PEOPLE OF MORAVIA, SILESIA, AND SLOVAKIA.

In the preceding paragraphs attention has been centered on Bohemia. In the remaining territories of the present Czechoslovak territories ethnic developments proceeded in much the same manner. There is a lack of the mound culture in Moravia and Slovakia, and hence of the first Keltic invasion, but the La Tène culture, representing the second Keltic stream, is partly represented. Merovingian graves are even scarcer in Moravia than in Bohemia and are limited to a small district in the south.

Silesia, although well peopled already in the neolithic period, is especially characterized by its urn field burials, hence by Slav population.

From Slovakia we have finds from the earlier neolithic, and from the late neolithic transitional period; eventually the whole territory

becomes covered by the urn field culture of the Slavs. A few spots of the La Tène culture are known, however, even from this country.

DEDUCTIONS.

The above brief review of the results of modern archeological and anthropological research in the lands of the present Czechoslovak Republic leads to the following deductions:

These territories have been peopled uninterruptedly since at least the early neolithic period, notwithstanding the influence and repeated invasions of outside peoples. The culture changed from time to time, but we may always observe the transitional changes from the older to the newer conditions, showing that there was no actual interruption. But the influx of various ethnic elements resulted in the gradual formation of a mixed people, composed of remnants of the old elements, as well as of the more recent comers. Due to the preponderant eventual influence of the Slav tribes, this population enters the historical arena as the Czechoslovak people, but the physical characteristics of this people show for long and even to this day their rather heterogeneous origin and admixture.

Taking Bohemia alone we find that archeologically and in rough lines the country is divided into three large areas. (See fig. 1.)

The central area was evidently peopled first and uninterruptedly from diluvial times. This area saw the development and passing of practically all the cultures of the country, though it was not influenced by all in the same degree.

The second area, the southwest, but sparsely peopled in early times, later remains long in the hold of the Keltic mound people, who eventually fuse with the Slavonic arrivals.

The third area, the northeast, also but sparsely peopled in the earlier times, becomes later the home of a people whose remains are deposited in the cremation urn-burial fields. This is the old Slav territory, the people of which with new additions from their sources farther northeast eventually prevail over all the country and give it its subsequent marked character.

In Moravia we have no mounds, and we may only recognize, outside of the diluvial and the neolithic periods, the northern Slavic urn-field area and a southern portion with cultural diversity. Slovakia resembles Moravia, except perhaps in respect of the diluvial epoch, but a great deal of research remains to be made in this country that for so long was blighted by the Magyar domination. Of Russia we know as yet but very little archeologically.

ARCHAEOLOGY VS. HISTORY.

Meager early historical accounts speak of the Boii as the oldest inhabitants of Bohemia, and of the Kotini as those of Moravia. Both

were Keltic tribes belonging to a stock of people which extended all over what is now south Germany and over Switzerland into France.

It was formerly supposed that the Keltic Boii and after them the Germanic Markomanni occupied all Bohemia; but Niederle has shown on the basis of both historical and archeological evidence that the settlements of the Boii were restricted to the southwestern part of the territory, and, judging from the archeological evidence, he ascribes to these people the mounds of southwestern Bohemia. These mounds agree closely with those of Bavaria and may be traced westward from that region. A historical note that in the year 114 B. C. the Germanic Cimbry, in their advance eastward from the Rhine, were at the foot of the Bohemian forest repulsed by the Boii, indicates the power of this tribe. But already before the first half of the first century A. D. their domination in Bohemia was at an end. This decline is possibly connected with the defeat which they had suffered from the Dacian chief Burvista and their subsequent concentration along the Danube, rather than with the advance into their territory of the Markomanni as represented by some historians.

The archeological finds, as already indicated, lead us to the conclusion that besides the Boii another Keltic tribe had reached the Bohemian territory in its more central parts, namely, the La Tène people. On the other hand, no graves or sites have as yet been found which could be attributed to the Germanic Markomanns and Kvades (Moravia), tribes which are mentioned by early historians. The Markomanni are supposed to have been led into Bohemia by Marobud eight or nine years B. C., but their domination, if such it was, seems to have been of a political rather than cultural nature, and they left no settlements or burials that could thus far be identified. The power of Marobud was doubtless built largely on the peoples he controlled, which explains the sudden loss of importance of the Markomanni after his defeat. The very seat of Marobud has not as yet been positively traced in Bohemia, all of which points to the ephemeral nature of the Markomann occupation.

THE SLAVIC TRIBES.

We have seen that on one hand both the archeological evidence and the early historical accounts indicate survivals in the country of remnants of the older populations and their eventual fusion with the Czech people. On the other hand, history as well as archeology has come to the conclusion that Slav tribes penetrated into the territories of the present Czechoslovakia long before the first mention in history of the Czech tribe. According to all evidence they were the people of the urn-field burials. These urn fields extend northeastward into territory which was the cradle of the Slavs;

their culture passes gradually into the historic Slavonic culture; the pre-Christian historic Slavs of these territories used cremation as their universal system of burial; and, finally, there is no scientific possibility of attributing the urn-field burials with their remains either to Keltic or Germanic tribes.

The rich archeological evidence renders possible the following estimates as to the coming of the Slavic tribes:

(1) Penetration of Slavs, with Lusatian culture, into northeastern Bohemia, and thereafter toward the center of the country, approximately 1000 to 800 B. C.

(2) Extension of these tribes over central Bohemia, their mixing there with the older population, and their development of a modified culture, about 800 to 600 B. C.

(3) Their numerical augmentation in northeastern Bohemia—500 to 200 B. C.

(4) Their gradual extension over the whole country—about 300 B. C. to the beginning of our era.

(5) A fusion of the preponderant Slav population with the remnants of the Keltic tribes—first to fifth centuries A. D.

(6) The addition of still other Slav bodies, one of which was the strong Czech tribe that eventually gave its name to the people of the country—fifth to sixth centuries A. D.

The earliest known Czech historian, Kosmas (b. 1045), had no idea that Bohemia had ever been occupied by any except the Slav peoples; but Kosmas's accounts show that even to his time there were over different parts of the Bohemian territories different related Slav tribes, with the Czechs occupying the center of the country. Due to forestation of large intervening tracts of territory and their different admixtures as well as contacts, these tribes developed certain cultural differences, traces of which, with traces of dialectical nature, exist in the Czechoslovak lands to this day. A series of the names of these late tribes has been preserved, but in the course of time the population has become so intermixed and fused that the names to-day are little more than memories. Nevertheless, anthropological examination of the people from different parts of the Czechslovak territories shows certain differences of type, which are doubtless connected with these earlier subdivisions and different admixtures of the people. (See fig. 6.)

The Slav tribes of Bohemia extended in historic times well beyond the boundaries of the country toward the south of the Danube, and in a southwestern direction into Bavaria (*regio Slavorum* of that country). These overflows later became Germanized.

From the twelfth century onward, a gradual German colonization, favored for political reasons by some of the earlier Bohemian kings,

and later by events, took place on the western and northern outskirts of Bohemia, with some penetration into the interior. This accounts for the present German population of the Republic, and for some recent German admixture.

In Moravia the knowledge of the earlier Slav tribes is more obscure; but there are several large old groups whose territorial distribution, with dialectic and other differences, have been better preserved to date than those of the tribes in Bohemia.

The southeastern part of Moravia and the subcarpathian territory toward the east, is occupied by the Slovaks. External influences which this tribe has suffered in the course of its existence have produced a certain amount of dialectic and cultural differences; nevertheless everything shows their common origin with the rest of the Slav tribes of the Czechoslovak territories.

CONCLUSION.

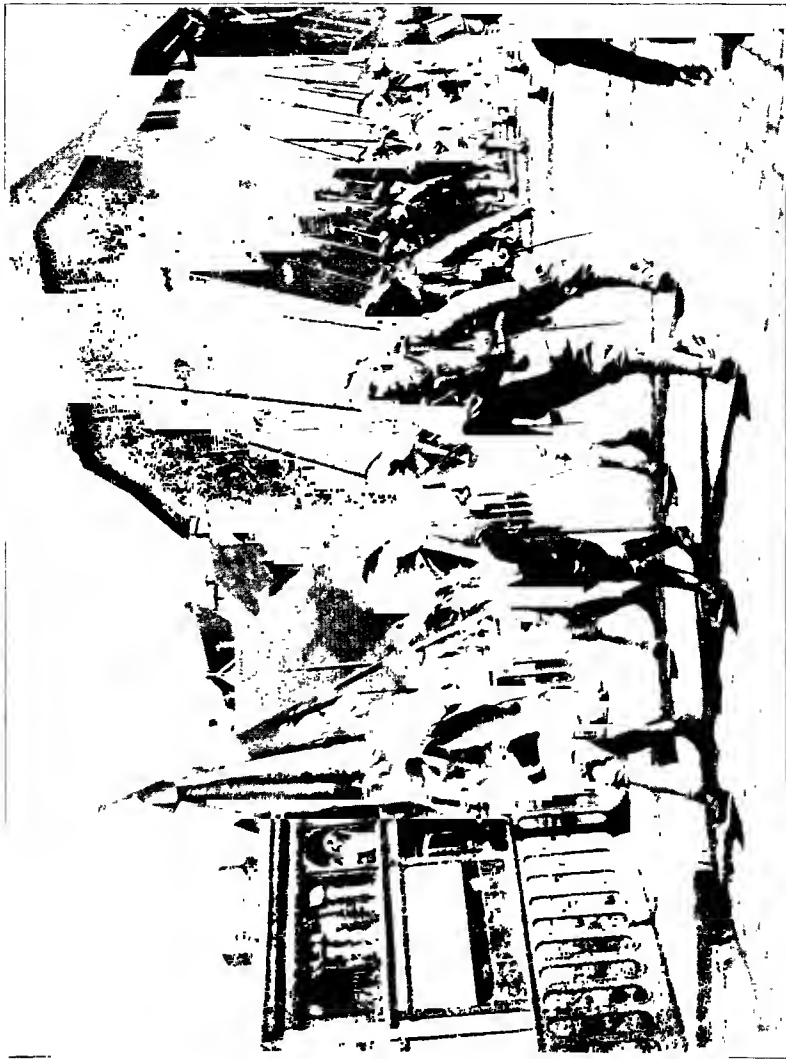
From the data here briefly given it is seen that the roots of the present Czechoslovak people are multiple, as in the case of practically all other now existing branches of the white race, and that some of them reach into hazy antiquity. Besides a little of the ancient blood, there is a Keltic and to some extent also a Germanic or Nordic infusion.

Mixtures of this nature, where the racial differences are not extreme, represent as a rule favorable biological as well as cultural conditions, and this with the intense struggle for existence imposed upon them by their geographical location, accounts doubtless for the historical prowess and acknowledged capabilities of the Czechoslovak people.

A few notes may be added concerning the physical characteristics of the present Czechoslovaks:

The general average stature of the adult males is 169 centimeters, of adult females 157 centimeters. The head is of good size and generally brachycephalic. The latter feature, as we have seen, is of historic development without any recent heterogeneous immigration. The brains, even in proportion to stature, show very favorable proportions.³ In pigmentation (color of eyes and hair) the people range from blonds to brunettes with preponderance of the latter. On the whole, physically as well as mentally, they represent a sound stock and one of favorable appearance.

³ See among others Weisbach (A.), *Körpermessungen verschiedener Menschenrassen*. Berlin, 1878.



CZECHOSLOVAKS FIGHTING WITH THE ALLIES IN FRANCE.



A TYPICAL CZECH WOMAN FROM MORAVIA.



CZECH CHILDREN, NOW LIVING IN BALTIMORE.

GEOGRAPHIC EDUCATION IN AMERICA.

By ALBERT PERRY BRIGHAM.

The evolution of geography on the west side of the Atlantic Ocean has, like every other great movement, been a continuous process. But we may for convenience say that about 30 years ago a new epoch began. Influences already at work came, in a somewhat accelerated manner, into fruition, until at the close of the period, the Great War has brought to geographic investigation and geographic teaching unexpected emphasis and a new array of problems.

In 1890 the National Geographic Society had been organized for two years and had published a few bulletins. The American Geographical Society had then pursued its work for nearly 40 years. It was domiciled in a downtown house, which with its narrow and elongated rooms and brownstone front seemed to be an old home of some well-to-do New York family. Its venerable and courteous secretary was on duty, almost a solitary worker, it would seem, conserving the books and periodicals that came to hand, and guiding to their use the rather rare inquirer who broke the solitude. A modest bulletin was published five times a year and occasional lectures were offered to the public.

The elementary textbooks of previous years abounded in definitions and in the routine of place geography but dealt little with the causal relations and the great network of facts and principles in which men are bound to the earth and to each other. The first textbook of physical geography which fully recognized the modern viewpoints of physiography was to appear in the following decade.

Very little instruction in geography as such was given in American colleges and universities. Harvard and Princeton had offered¹ courses in geography before 1860, Wisconsin, Cornell, and Yale Universities introduced the subject in a limited way about 10 years later, but it gained no real place in the university consciousness. In 1900 only 12 of our higher schools were teaching geography, and this was mainly of the physical sort, and under the wing of geology.

¹ Geography in American and European Universities, R. H. Whitbeck, *Jour. Geog.*, XVIII, 129-141, April, 1919.

The mapping of the national domain in an adequate and detailed manner was well started, but less than 360,000 square miles had then been covered by surveys for this purpose. New York had then contoured maps covering little more than 1,000 miles of surface, and the great States of Illinois and Wisconsin were, as regards maps, in a backward condition.

The conditions as thus rehearsed do not mean that there were no advances in American geography prior to the year 1890. In the realm of regional knowledge, the geological and natural history surveys of New York and other States had been long assembling geographic data of many kinds. Ten years before this date the fugitive and fragmentary organizations for the study of our national domain had been succeeded by the United States Geological Survey. In that Survey, Powell, Gilbert, Dutton, and others laid broad and deep the foundations of American physiography.

For a period of 20 years, under the directorship of Maj. J. W. Powell and Dr. Charles D. Walcott, the annual reports of the Survey included a series of scientific essays, which were geographical as well as geological in their scope—extended papers written in non-technical style, papers which may be regarded as classics of earth science. Among these essays were the following: Dutton's Hawaiian Volcanoes and the Charleston Earthquake; Gilbert's Topographic Features of Lake Shores; Chamberlin's Artesian Wells, Terminal Moraine of the Second Glacial Epoch, and other glacial papers; Russell's Glaciers of the United States; Shaler's Essays on Seacoast Swamps, Harbors, Fresh-water Morasses and Soils, and his regional accounts of Mount Desert, Cape Ann, Cape Cod, and Martha's Vineyard.

There was also growing, 30 and 20 years ago, an important geographic literature in hydrography and irrigation as embodied in various publications of the Geological Survey.

A review of the field at the present time shows marked progress along several lines. In the early nineties the famous report of the Committee of Ten to the National Educational Association marked a new era in secondary and elementary geography. The subcommittee for geography contained some of our most eminent students of earth science, and a group of texts embodying their recommendations soon found entrance into the schools. The result was an over-emphasis upon physical geography, from which in recent years there has been a reaction, but the impetus given to rational geography was nevertheless of great value. Interest in human and relational geography was awakened, and new texts were prepared for geography in the grades. These texts have recognized both physical and human and have developed in forms suitable to the youthful mind the relations of men to land forms, climate, soils, and all natural

resources, as well as the relations of human groups to each other. Thus, geography has to a considerable extent become known as a social study, though it may be surmised that those who put most emphasis upon this aspect of it are those who have the least appreciation of physical geography and of the great field of geographic influence and human responses.

Geography now has a constantly enlarging place in our universities and colleges. In the year 1910-11, taking 24 American universities, the enrollment of students in geographic courses was 3,980. In the year 1916-17 the number had risen to 9,807, the University of Pennsylvania having over 2,000 and the University of Wisconsin more than 1,000. In the same academic year the courses offered in single universities ranged from 1 to 19. The latter number of geographic courses was offered by the University of Chicago, Columbia offering 16, Wisconsin 15, Nebraska 15, Harvard 14, California 11, and Pennsylvania and Yale each 10. At least 9 of the higher institutions in the State of New York are now regularly offering a more or less extended outfit of courses in geography.

More than 30 phases or regions are represented in the titles of the courses offered. Among these are physical, commercial, climatic, mathematical, cartographic, agricultural, political, educational, and conservational phases, geographic influence, and the general principles of the subject. In addition there are courses upon the United States, upon single States, upon several of the continents and upon the oceans. One course is offered in the great and fascinating field of urban geography. Advanced degrees in geography have been given by the following universities: California, Chicago, Columbia, Harvard, Cornell, Missouri, Nebraska, North Dakota, Princeton, Wisconsin, and Yale. Other schools that offer somewhat extended opportunities in geography are Minnesota, Michigan, Washington (State), Wellesley, Oberlin, Iowa, Illinois, and Colgate.

First in order of time and most widespread in university instruction to-day is the physiographic content of geography. There is now, however, an important growth on the side of commercial geography. This phase, not long ago, and still in some minds, regarded as on a level with bookkeeping and typewriting in the shorter and more elementary courses of business schools, has for some years been coming into secondary schools as a rational subject and a substantial discipline. It is now taking its place as an advanced subject in colleges and universities, and is an important part of the curriculum in schools of business administration, as in Harvard, Columbia, and Pennsylvania.

Geographic societies have had much to do with recent advances in geography. The National Geographic Society, from its small beginnings a third of a century ago, has grown to vast size and com-

manding influence. With its membership far beyond a half million, its large funds and its brilliantly illustrated magazine, it brings geographic information to the attention of perhaps some millions of people each year. In addition it has subsidized and directed exploratory research in several parts of the world, including Alaska, South America, and the Polar regions.

In the period named the American Geographical Society has twice removed to new homes to fit its expanding work. Its library has been rapidly built up, its map collection enlarged, and its publications extended and enriched. It has become a center of geographic influence for the Western Hemisphere and has adopted elaborate plans for its future work. On a less extended scale similar progress has been made by the geographic societies of Philadelphia and Chicago.

In 1904 the Association of American Geographers formally began its work with a program of papers given at its meeting in Philadelphia. Here was founded, it is believed, the only geographic society in the world which adheres to standards of expert membership. Its objects have combined research and educational advance, and much of the new interest in geographic subjects, in the whole range of geographic education, is due either directly or indirectly to its activities.

The membership of this association is little more than 100, but it includes most of the professional geographers of America, their affiliations in various degrees relating them to the geographic aspects of geology, the biological sciences, climatology, and agriculture on the one hand, and to history, economics, sociology, and statistical studies on the other.

Out of this association has developed, since 1914, the National Council of Geography Teachers, which has now organized State councils in a majority of the States and is an effective force in promoting geographic advancement in the elementary and secondary schools of the entire country.

Coordinated with the National Council is the publication known as the *Journal of Geography*. This periodical, founded by Prof. Richard E. Dodge at Columbia University, in 1897, and taken over at a later period by Prof. R. H. Whitbeck, of the University of Wisconsin, has recently been published by the American Geographical Society of New York under the editorship of Director Isaiah Bowman. For several years it has been affiliated with the National Council, and it is soon to become their specific organ under the direction of Prof. George J. Miller, of Mankato, Minn., the secretary of the council. For 23 years this journal has been a powerful force in American geographic teaching.

Thus by gradual processes have come into being effective and powerful means for promoting geography in this country and raising it to the level of efficiency which it has reached in some of the countries of Europe. We have the Geological Survey, the Department of Agriculture, the Department of Commerce, and other organizations of Government supplying day by day and year by year vast stores of geographic information. We have several mature societies engaged in research and in reaching intelligent readers and citizens everywhere. We have growing interest and effective agencies at work in elementary education, and it may at last be said that the need of geography is now so fully realized in our universities that the demand for qualified teachers exceeds the supply.

Thus forward movements in geographic education have been in progress for many years. But none could have foreseen the widespread and profound awakening to geographic facts and principles that was to come with the recent War of Nations.

"If we glance at each of the great continents of the globe we see how truly the war is called a World War. Of Europe's approximately 4,000,000 square miles of territory, seven-eighths was directly involved in the conflict. For Africa the fraction is larger, 32 out of 33 parts having been in belligerency. Asia, with her 17,000,000 square miles, shows twenty-four twenty-fifths of her territory involved in the conflict, while Australia was completely in the throes of war. Turning to North America, we shall find that four-fifths of her area of nearly 10,000,000 square miles is occupied by two of the great countries that were in the struggle. Only about one-half of South America remained nominally neutral. Summing it all up, of the 52,000,000 square miles and more of territory making up the land of the entire globe, exclusive of Antarctica, more than 45,000,000 square miles belong to the belligerent nations, and the remaining few million were more or less profoundly affected.

"The extent of the war and of world changes may be seen if we glance at the map of Africa. If Germany had won, she would have taken possession of the Belgian Congo and of adjacent British and French colonies on the south and north, making a solid block of German sovereignty across equatorial Africa from the Atlantic to the Indian Ocean. What the extent of her aggressions in North Africa from Gibraltar to Suez would have been we can not say, but that it would have been large there can be no doubt. As it is, however, Germany is excluded from Africa, and both British and French possessions are enormously enlarged. Furthermore, the great obstacle has been removed to the construction of the Cape-to-Cairo Railway. That obstacle was a thousand miles of German territory in East Africa.

"Germany's profoundest aggressions and her largest hopes were involved in her project for a Middle Europe. This meant, to begin with, the actual subjugation of seaports in southern England, the destruction of France as an industrial nation by the acquisition of her supply of coal and iron in the north and of every industry on her Belgian border, the subjugation of Belgium, the ultimate over-running of Holland, and the free use of the great corridor route down the Danube through Austria-Hungary, Bulgaria, and Turkey to Constantinople, Syria, and the Persian Gulf. It meant that the entire Old World, the great land mass of three continents, was to be bisected in its very vitals. It meant ultimately the destruction of the British Empire and the throttling of India, which would be left in a state of anarchy or under the German heel. It meant ultimate aggressions in China, commercial or political sovereignty of South America, and, in the not distant future, German vengeance upon North America."²

Geographic conditions have in all ages influenced the conduct of war and controlled strategic plans and tactical operations. Never before, however, has a great number of geographical and geological experts attended upon armies at the front or supplied in such ample measure the data for determining the outlines of countries and the terms of peace. On every front, English, French, American, German, and others, students of earth science were pitted against each other in studying natural resources and supplies, lines of communication, drainage, the location of divides, the forms of valleys and escarpments, the fluctuation of streams, the soil, subsoil, and bed-rock, the position of water table, climatological conditions, etc.³

Military geography, it may be said, is of interest to specialists in war, but the changes in political geography and economic relations following upon the war have made this branch of knowledge vital to every citizen of the world.

The war has given geography a fresh and unwonted interest in America, because we have gained a new sense of the significance and permanence of international relations. This is true, whatever forms these relations assume, whether of expanded trade, courts of arbitration, or any kind of association to promote peace and justice. The principle involved has been elsewhere set forth by the writer.⁴

"The war has vividly exhibited the financial interdependence of all nations. American consuls in foreign cities have for years protested against the failure to provide American banking and

² *Geography and the War*, by the present writer, *Jour. Geog.*, XIX, 91-92, March, 1920.

³ See outline of address by Col. Alfred H. Brooks, Sc. D., *Proc. Educ. Congress*, Dept. Pub. Instruction, Commonwealth of Penn., Harrisburg, 1920, pp. 540-547. Also by the same author, "The Use of Geology on the Western Front," *Professional Paper* 128-D, pp. 85-124, in *Shorter Contributions to General Geology*, U. S. Geol. Surv., 1920.

⁴ *Geography after the War*. *Educational Rev.*, vol. 57, p. 284, April, 1919.

credit facilities in regions where trade was desired and they have decried the American sloth which did not learn foreign languages and acquaint itself with alien needs and tastes. The war has started a new era in American relations to the rest of the world. Our money, our food, our technical skill, and our manufactured products will be wanted everywhere. The American traveler will no longer look longingly but in vain to find the American flag in ports across the seas. A world league, if it is to be and whatever it may be, will involve relations of communication and transportation, of production and manufacture, and of markets and economic dependence. The character of populations, their distribution and movements, mean a world of close and neighborly fellowship, the only alternative to friction and bloodshed. Geography offers much of the knowledge and will soften prejudice, reveal and avert our difficulties, and direct our progress."

In the National Research Council geography now has its appointed representatives organized in affiliation with the geological representatives of earth science. We have already noted the fact that the National Geographic Society has supported field research in several important fields. Within a few months the American Geographical Society has made a significant departure from previous policy in the decision to adopt henceforth as its chief work the study of Latin America. Upon the model of the Royal Geographical Society in taking Africa, for example, as a special field, it is deemed worthy and appropriate for the senior geographical society of America to devote its money and its expert knowledge to the southern lands of the Western Hemisphere.

As the passage just cited intimates, geographic knowledge has become a new factor in the conduct of business. Conditions of production and manufacture, of transportation, market and sale, the world over, require for their balancing, both intensive and extensive familiarity with the facts and principles of geography, and in every phase of geography, physical and human. Here is a body of knowledge that is not supplied by history, or economics, or by any branch of physical science. Geography in its program has added the higher to the lower realms of education and must attempt a comprehensive study of earth and man, a problem vast and baffling and at the same time mandatory and inspiring.

Apparently as a result of the patent efficiency of geographers in the Shipping Board, the War Trade Board, and other Government organizations, it is now not uncommon for large concerns to employ geographical experts to solve the problems and answer the difficult questions involved in world trade. Resources, climate, distances, routes, racial traits, and local tastes are all here involved.

It is therefore apparent that not only in the schools but in the field of business as well, geography is now recognized as belonging in the field of research. It has outlived the stubborn prejudice that there was nothing in it beyond a purely elementary discipline.

As geography is enriched with new and rational material, geographical discovery is taking on a new meaning. Much that is even now on the map with a fair degree of accuracy must be rediscovered and so interpreted as to lead to real knowledge of it and the highest uses of it.

While some ancients, notably Strabo, had penetrating notions as to the origin and meaning of features of physical geography, we are most interested to know now how far Herodotus, for example, and Eratosthenes and Strabo and Ptolemy knew the world of their time in Europe, Asia, and Africa. So in the era of modern explorations from Prince Henry to Columbus, Magellan, Capt. Cook, Livingston, Richthofen, Lewis and Clarke, Peary, Scott, and Amundsen—they taught us in the sphere of quantity—it was expansive geography in large part, with quality and substance as incidental elements. Now we seek intensive geography; quality is the main thing, and relations are paramount. We interrogate relief, climate, vegetation, animal life, fruits, grains, minerals, and soils as they are used by man or might be used by man.

We seek for causes and effects; in other words, we demand to know what the geographic influences are, both for the intellectual satisfaction of knowing and for the concrete purpose of conforming life to conditions with the least waste and the most profit.

Related to this new aspect of discovery and study of regions is a new and serious intellectual equipment for travel. Most men have traveled very much as one goes 20 miles to market, or as a child wanders in the field on a vacation day. The rather aimless pastime of chasing butterflies, gathering chestnuts, or picking wild berries is well, but the mature traveler must now do more. He must take much with him, that he may bring back more. The "White Cattle" and the "Dog's Palace" may suffice the new rich to have seen on the plains of the Po and in Venice, but the real traveler will absorb and bring back Italy as a unit of environment, shaping a human group in its ways and works for two or three millenniums.

Such work will not of necessity be done formally or pedantically, or be shaped by dry rule, but by a trained geographic vision which knows mountain and plain, climate and soils, products and people, a spirit that asks and in some measure sees why things are as they are.

Some measure of this intensive and causal knowledge of nations and of the world is needed by all and is highly important to all public teachers and to all who are, or who aspire to become states-

men. Not a few costly errors have been made during recent settlements and in the wars and diplomacy of centuries because public men were ignorant of geography.

Those who are to be statesmen can not, in general, be selected while young and trained for their careers. At least in a democracy, public officials may come from any class and any home. Statesmen will in the long run be made out of the material in our schools and their course will in turn be shaped by public opinion. If the public is ignorant of the world, their action will be haphazard, based on ignorance and on desire for party advantage. We are facing economic readjustments which have to do with the resources, the transportation, the tastes, and the industrial conditions of every country in the world. We would not debar our diplomats from training in politics or from the experience and graces of the drawing room, but we would give them knowledge and a consequent sense of being at home in the lands to which they are accredited. Such training is to a large degree in the sphere of geographic education.

In brief summary we may say that down to the year 1850 geographic textbooks in America were of the gazeteer type, valuable as stores of information but having small value in education. During the following 40 years the atlas type of geography prevailed, placing thus a new value upon the use of maps, and locational geography was in the forefront and marked by excess of emphasis. The period, however, shared in the impulse that came with the emergence of the doctrine of evolution and was enriched by the anthropogeographic studies of the Germans and the French and by the rise of scientific physiography in America. Rapid progress, however, as shown in geographic education and geographic research, goes back in the main through the 30-year period to which reference has been made.

The next 30 years will go far to achieve the growth and realize the aims that will round out a century since gazeteer geography held the field. Geography will, we believe, become a cardinal theme in elementary and secondary teaching, that our youth may be fitted to live in a world of nature, of resources, of races and nations. There is, perhaps, no other subject which so well pictures what that world is and so effectively links together and utilizes the combined harvest of the natural and the social sciences.

Out of such perfected geographic training will come not only effective intelligence for citizenship but the training of experts for commercial undertakings, for military necessities, for consular and diplomatic work, and for the intensive study of new or little-known regions.

Along with strong development in education from lowest to highest will proceed the perfecting of our maps, those summaries of

geographic education which may be made to express visually the relief, the resources, the industries, the distribution of people, and almost every phase of human activity in any and every part of the earth.

So far as expression can set forth the facts and principles of man and the earth, the finished product of geography will more and more be found in thoroughly attractive and informing descriptions of regions. We have had, and must always have, various types of description, the gazeteer, the guide book, the encyclopedia article, the popular notes of the unprofessional traveler, and the special or technical report. All these, however, should contribute to and, in turn, be enriched by regional descriptions which are scientifically accurate, serious without being too technical, expressed in good literary form, and giving balanced, interesting, and useful knowledge for the man of business, diplomacy, or pleasure, who needs to know the particular region. Even travelers see but a small part of the world, they deal in samples and they must exhibit and exchange their wares in order that anyone may know the earth widely.

The world's stock of geographic knowledge has been gathered through multitudinous agencies through the centuries. Commerce, war, love of adventure, thirst for knowledge, immigration to new lands for a fresh experiment in living—all have had their part. It remains for geographic education to order this mass of material, develop geographic principles, and help toward a better use of the earth and its gifts.

PROGRESS IN NATIONAL LAND RECLAMATION IN THE UNITED STATES.¹

By C. A. BISSELL,
Engineer, U. S. Reclamation Service.

[With 10 plates.]

The full importance of national irrigation can not be measured in dollars and cents. In the building of new Commonwealths in the arid West the Government is utilizing largely its own undeveloped resources. It is creating opportunities for its citizens to establish themselves in permanent homes in which patriotism, loyalty, and civic pride are bred and fostered. The primary purpose of the Reclamation Act was to create homes, and this purpose has been fulfilled richly and abundantly. Viewed from this standpoint, no one can deny that national reclamation has amply justified all its exponents declared for it.

Since 1902 the Reclamation Service has constructed the irrigation system to supply completely 1,780,000 acres of land. Also, the capacious storage reservoirs of the Government are furnishing a supplemental supply of stored water to 1,000,000 additional acres in other projects, or a grand total of 2,780,000 acres.

On the Government project lands are 40,000 families in independent homes. The population in cities, towns, and villages in these Government projects has been increased by an equal number of families. That is to say, on the 1,780,000 acres reclaimed there are now profitably employed and satisfactorily housed 400,000 people. The arguments for increasing and making permanent the Nation's virility, prosperity, and growth by creating more homes of this kind were never more forcible and unanswerable than just now. American people can not rightly claim to have measured up to their opportunity until the deserts of the West and the unused agricultural lands of the balance of the Nation have been replaced by vistas of prosperous farmsteads.

¹This article is in continuation of papers printed in the Smithsonian reports for 1901, pp. 407 to 423; 1903, pp. 827 to 841; 1904, pp. 373 to 381; 1906, pp. 469 to 492; 1907, pp. 331 to 345; 1910, pp. 169 to 198; 1915, pp. 467 to 488, all of which are out of print.

Measured by the yardstick of the financier—the dollar—the results of the Reclamation Service activities are interesting.

As a creator of wealth, its service to the Nation and the State has been as great as in its principal task of home making. Out of the uninhabited and almost worthless desert it has carved an empire of nearly 2,000,000 acres intensively cultivated, and producing crops whose annual average gross returns per acre are about double those for the rest of the country.

Since the first Government ditch began turning its waters upon the land, in 1905, the crops produced on the reclaimed lands have had a total value of more than \$250,000,000. The present annual crop returns are now nearly \$90,000,000, not including the value of crops grown on the million acres outside of projects which are supplied with stored water.

The increase in land values has been enormous. In 1902, the beginning of Government irrigation, the average value of the desert lands in the projects did not exceed \$10 per acre. The total value, therefore, of the 1,780,000 acres in Government projects did not exceed \$17,800,000.

Government irrigation has increased the value of the project lands \$200 per acre, or a total of \$356,000,000. It has increased the value of the 1,000,000 acres in other projects by \$100 per acre, or \$100,000,000. The increase in the value of land in the cities, towns, and villages within projects is easily \$100,000,000, or a total increase in land values of \$556,000,000, due to this work.

In connection with the above summary no consideration has been given to 1,138,000 acres of land included in Government projects which will be irrigated when the engineering works are completed, the present market price of which has increased at least \$50 per acre by reason of this fact.

The increase in the price received for State lands included in the projects and now mostly disposed of was at least \$3,000,000 of direct revenue derived by the States.

Dividing the acreage reclaimed—1,780,000—into the net cost of the works of \$122,645,000, we have a cost of approximately \$69 per acre for the lands in reclamation projects to which the Government can now deliver water. This cost, however, includes the cost of serving stored water to about 1,000,000 acres of land under the Warren Act. If these lands be included, the average expenditure per acre benefited is less than \$45 per acre, and this cost includes large storage works and canals useful for future reclamation on projects now being completed, the utilization of which will further reduce these figures of cost.

ADVANTAGES OF IRRIGATION FARMING.

Agriculture in the arid region where irrigation is feasible has several important advantages over that in the humid region. The soils of the arid region by the nature of the case have generally not been leached of their mineral plant foods as have those in the humid region, and they are therefore much richer in this respect on the average and are seldom or never acid, as are soils in the humid region. This quality has the disadvantage at times of leaving the arid lands charged with hurtful alkalis, which seldom remain in the soil of the humid region on account of their solubility, but where the injurious salts do not predominate the general principle of abundance of mineral plant food obtains and constitutes a distinct advantage over the soils of humid regions.

There is much advantage in being able to apply water to growing crops at just the time and in just the quantity needed and to withhold it at will. Where the water supply is ample this constitutes a very important advantage in arid regions.

Another striking advantage is the preponderance of clear days in an arid region, where the absence of rainy and cloudy weather affords a much larger percentage of sunshine than is found in humid regions. As sunlight is one of the most important essentials of healthy plant growth, this advantage is quite important.

Resulting from these advantages, it appears that the average gross product of agricultural crops on reclamation projects is just about double the average yield from nonirrigated lands in the country at large. The larger product obtainable per acre from irrigated lands justifies and permits a more careful and intensive cultivation, which with a favorable climate and controllable water supply, yields more certain results than the same care in the humid region.

This means that as much product can be obtained from a 40-acre tract under irrigation as from the average 80-acre tract in the humid region. This, of course, requires more labor per acre, but much less labor in proportion to product. It permits and encourages intensive cultivation and smaller holdings and consequent greater centralization of population. The result is that the isolation of country life is to a large extent eliminated, as the irrigating farmer will have fully twice as many neighbors within a given radius as his prototype in the humid region. The social advantages thus obtained react upon the character of the people and of the communities and other conditions characteristic of irrigated regions have a similar effect.

Cooperation with his neighbors is forced upon the irrigator because it is usually impracticable for him to irrigate his land without such cooperation, the feasible irrigation projects usually being in tracts of many thousands of acres accommodating thousands of families

and giving rise to towns, villages, and characteristic civilizations of their own. This condition stimulates the civic conscience and attention to public affairs of common interest, so that the local governments that grow up under such conditions are usually of a superior order and controlled by a superior intelligence on the part of the population living thereunder.

ARE PROJECT SETTLERS PERMANENT?

In order to determine to what degree settlement on reclamation projects is permanent, an investigation was made in 1919 of a number of representative projects:

Five of the projects selected for investigation, namely, Huntley, Minidoka, North Platte, Shoshone, and Umatilla, were thought to have experienced unusually trying conditions for the settlers, and one—Boise—was thought to have been quite favorable. Letters were sent to the project managers of these six projects asking the number of original settlers still in possession and the number of transfers made by other settlers, together with any proper explanations.

Although the figures are probably not infallible, they are as nearly correct as possible. The margin of error is doubtless small in any case. The chance for greatest variation is in the number given for total farm units, because these are constantly changing and subdividing.

One of the projects—Minidoka—was also checked up by consulting the tract books in the General Land Office in Washington.

Following is a tabulation from the reports received:

Project.	Total number of farm units.	Settlers still in possession or who have satisfied homestead requirements.	Per cent of total.	Total number of settlers.	Number of settlers per farm unit.
Boise, Idaho.....	1,107	987	89.1	1,273	1.14
Huntley, Montana.....	589	383	65.0	839	1.42
Minidoka, Idaho.....	1,609	299	55.8	2,709	1.68
North Platte, Nebraska-Wyoming.....	1,337	723	54.0	2,155	1.61
Shoshone, Wyoming.....	609	405	66.5	902	1.48
Umatilla, Oregon.....	196	136	69.3	289	1.47
Total.....	5,447	3,533	65.2	8,167	1.49

A difference will be noted between the total number of farm units for each project and the total number as listed in the annual reports of the Reclamation Service. The figures given above exclude farms on private and State land inside the projects and farm units which have not been entered upon, except in the case of North Platte, which

are divided as follows: Public-land units, 982; private-land units, 308; State-land units, 47. The numbers are taken from special reports of the project managers and are therefore as recent and as nearly accurate as possible.

From the figures quoted, it is computed that the average number of settlers to a farm unit on the Boise project, where conditions were favorable, was 1.14, or slightly more than one—truly a remarkable showing when it is considered that farms in general often go through many changes in ownership; and only 1.68 on the Minidoka project, where conditions were adverse.

Opponents to homestead and reclamation acts have argued that many settlers take up their farms merely for speculation. Although no effort has been made to learn the changes on reclamation projects after title had been obtained, results indicate slight changes during the time of proving up.

Before the end of the period required for residence, settlers may relinquish their right and for money consideration pass on the farm unit. This can safely be done only when the relinquishment paper is filed simultaneously with another entry. Any such transactions may come under the notice of the project office if the settlers are known personally. Giving up an entry does not by any means indicate that the entryman has failed to make good on his farm. It may show quite the contrary—that he has succeeded so well he is able to sell out his improved farm for a good figure. This kind of speculation can hardly be avoided.

The first few years of the Reclamation Service were the most severe for the project settlers. Water was not available at this time, and under the law settlers could not be prevented from taking up land which might not receive water for years. Having seen how often it worked hardship for settlers to struggle along until water was ready, the service secured the passage of a law which prohibited the entering of farm units until the irrigating system is in operation, resulting unquestionably in even greater permanence of settlers on projects opened under these conditions.

The investigation has shown conclusively in connection with Federal projects that there is not the slightest basis for the statement so often and so loosely made that "throughout the newer parts of America at least three settlers in succession attempt to develop a farm before one succeeds."

IRRIGATION PROGRESS.

During the past year the operation of the Government under the various reclamation laws has continued to develop the resources of the projects undertaken, as shown by the gradual increase in the

area for which the service can supply water, the increase in areas actually irrigated and cropped, and the increase in the value of crop produced. This progressive increase is shown in the following table, which gives statistics only for those areas covered by crop census, excluding practically all those additional areas which are served from the works of the Reclamation Service under Warren Act contracts and from which crop statistics were not obtainable. It is estimated that, including these areas, the crop value in 1919 amounted to \$150,000,000 or over.

Development of Government irrigation project.

Year.	Irrigable acreage.	Irrigated acreage.	Cropped acreage.	Crop value.
1913.....	1, 181, 362	694, 142	637, 227	\$15, 676, 411
1914.....	1, 210, 875	761, 271	703, 424	16, 475, 517
1915.....	1, 330, 222	814, 906	757, 613	18, 164, 452
1916.....	1, 405, 452	922, 821	858, 291	32, 815, 972
1917.....	1, 502, 468	1, 026, 663	966, 784	56, 462, 313
1918.....	1, 601, 934	1, 119, 566	1, 051, 193	66, 821, 396
1919.....	1, 636, 159	1, 187, 255	1, 113, 469	83, 974, 137

The statistics given in the above table do not, however, tell the whole story. The easy terms of repayment granted by the Government and the high prices received for their products have combined with the other favorable conditions and with the industry of the people to produce a condition of prosperity beyond the indications of the bare statistics.

No new projects have been undertaken within the past year, as there have been no funds available for this purpose. The gradual decline in the receipts from the sales of public lands, due largely to the wholesale disposal of these lands under the operation of the 640-acre homestead act, has naturally greatly restricted the operations under the reclamation act. The small payments provided by law from the irrigated lands have kept the returns from the constructed projects to a low point. It is now necessary, under the provisions of existing law, to set aside \$1,000,000 per annum from these receipts to repay the advances to the reclamation fund which were provided by the act of 1910, known as the "bond loan." It has been possible on this account only slightly to extend the irrigated area by some extension of canal systems and to take care of water-logged conditions as they have arisen on some of the projects.

CONSTRUCTION RESULTS.

In spite of the adverse labor conditions and the absence of opportunity for the undertaking of new projects, it is noteworthy that

during the fiscal year 1919 the amount of excavation accomplished by the Reclamation Service totaled nearly 14,000,000 cubic yards, and 575 miles of canals and drains were constructed. Reservoir capacity on all projects totals 9,400,000 acre-feet. The following table gives a brief summary of the construction work accomplished by the Reclamation Service in the 17 years of its existence:

Summary of construction results to June 30, 1919.

Item.	Unit.	Number or quantity.
STRUCTURES.		
Canals.....	Miles.....	10,834
Tunnels.....	do.....	27
Dikes or levees.....	do.....	97
Irrigation and drain pipe.....	do.....	500
Flumes.....	do.....	120
Canal lining, concrete.....	do.....	308
Roads.....	do.....	970
Telephone lines.....	do.....	3,126
Transmission lines.....	do.....	615
Canal structures:		
Concrete.....		32,722
Wood.....		64,423
Bridges.....		7,000
Culverts.....		9,044
Buildings.....		1,374
MATERIALS HANDLED.		
Excavation:		
Earth.....	Cubic yards.....	154,473,487
Indurated material.....	do.....	9,913,065
Rock.....	do.....	8,409,722
Total.....	do.....	172,796,274
Volume placed in dams:		
Masonry.....	do.....	2,087,991
Earth.....	do.....	10,220,671
Rock fill and crib.....	do.....	1,203,386
Total.....	do.....	13,512,048
Riprap.....	do.....	1,892,728
Paving.....	Square yards..	819,408
Concrete.....	Cubic yards...	3,023,446
Cement.....	Barrels.....	2,971,330

RECLAMATION PROJECT OPERATIONS.

The Salt River project in Arizona is being operated by the local organization of water users under a contract by which the Secretary of the Interior on November 1, 1917, turned over the works and the income of the large power plants constructed in connection with the project. It is in a prosperous condition, and the income from power

a good deal more than pays the construction charges. The Government connection with this project is confined to occasional inspection and supervision, as provided in the contract. The ground

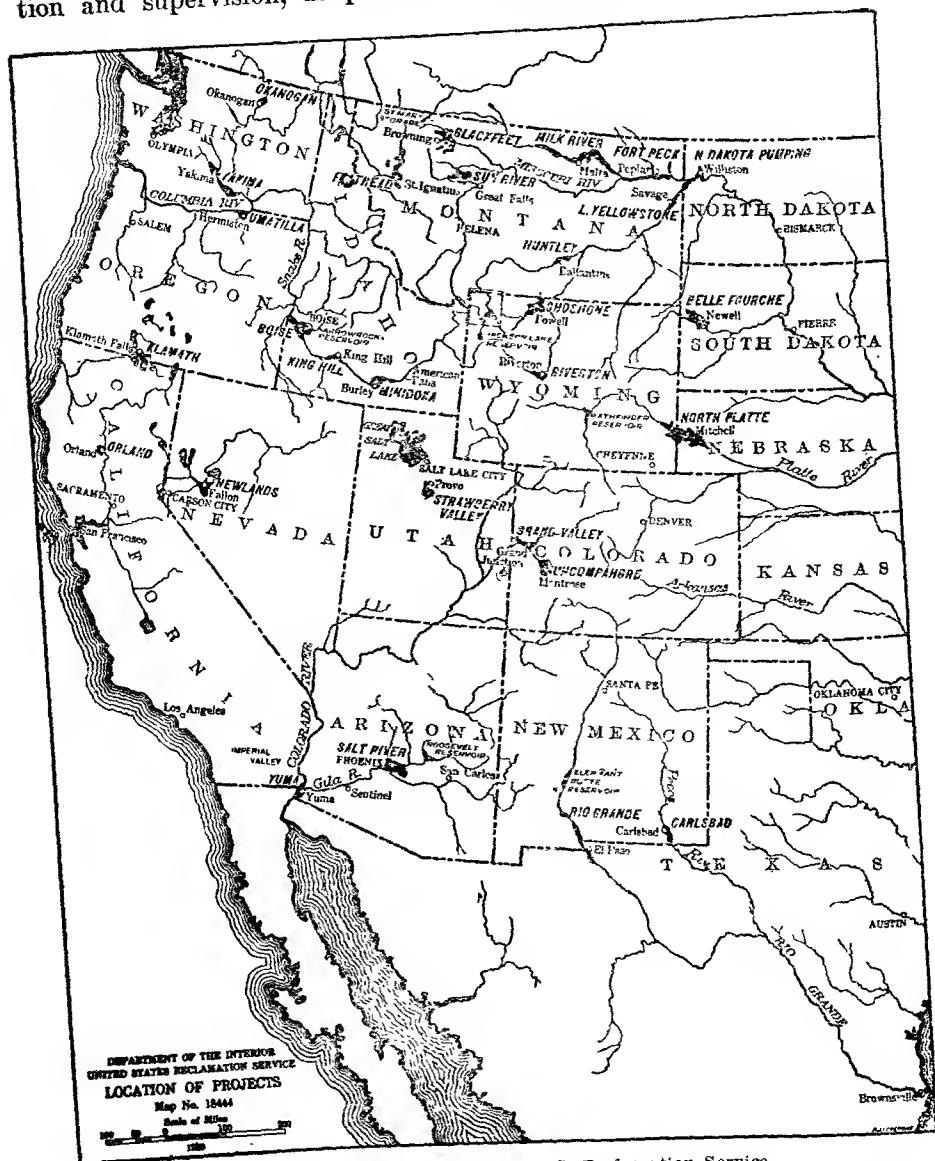
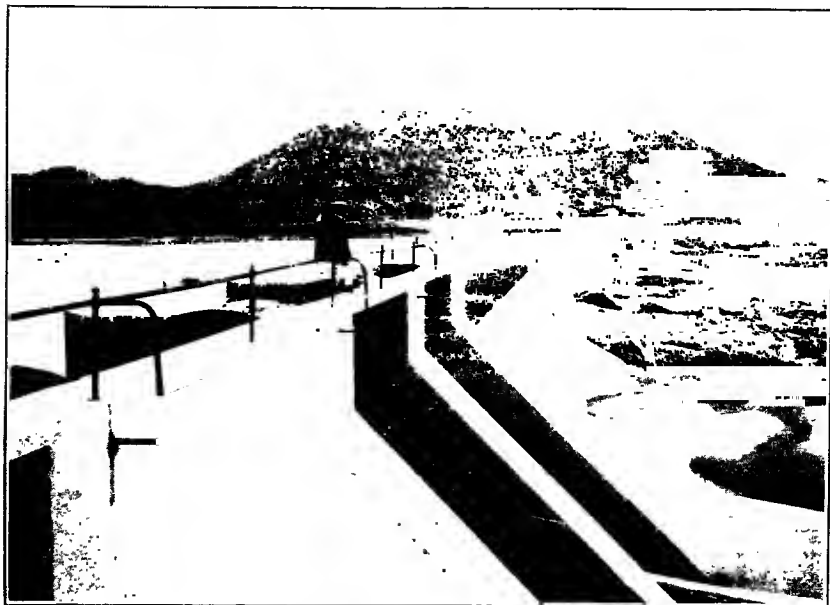
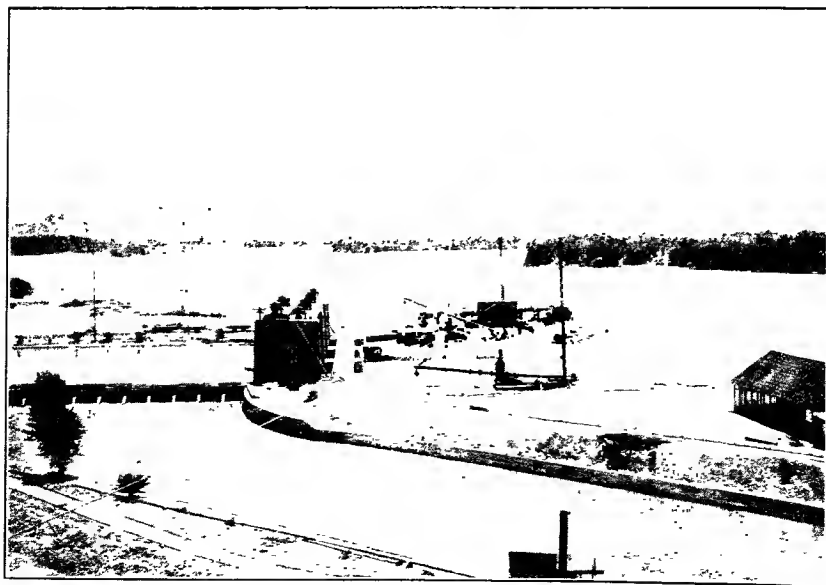


FIG. 1.—Location of projects, U. S. Reclamation Service.

water is rising on this project and will require early attention in order to prevent injury to a considerable area of land. This has been investigated by the water users' association, which is alive to the problem and will doubtless take necessary action.



1. GRANITE REEF DAM, SALT RIVER PROJECT.



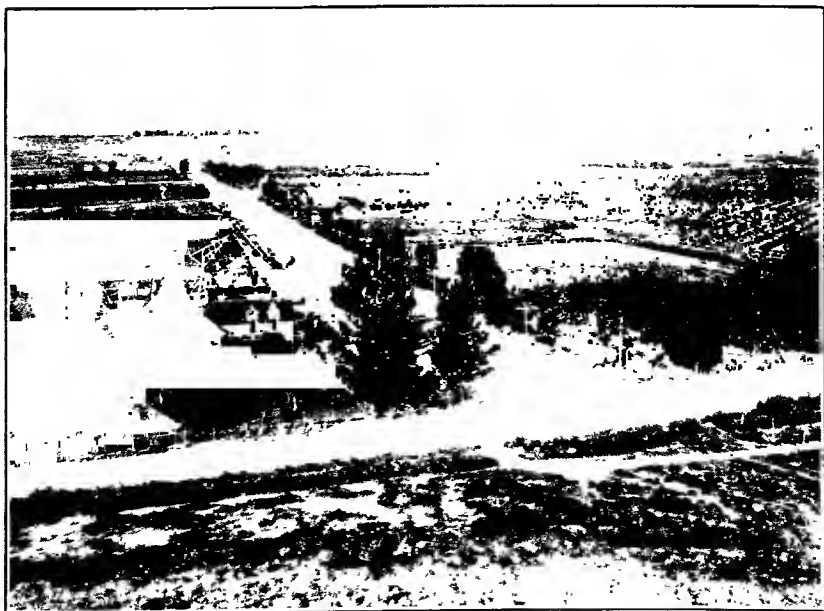
2. LAGUNA DAM, YUMA PROJECT.



HIGH LINE CANAL AND PUMPING PLANT, GRAND VALLEY PROJECT.



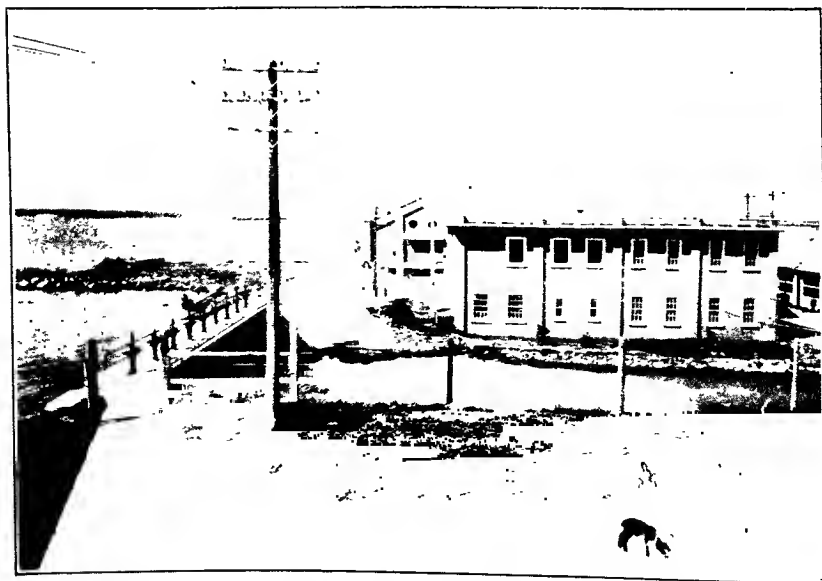
1. HARVESTING THE ALMOND CROP, ORLAND PROJECT.



2. IRRIGATED FARMS, UNCOMPAHGRE PROJECT.



1. NEW RANCH IN PEACH VALLEY, UNCOMPAGRE PROJECT.



2. OFFICE BUILDING AND POWER HOUSE, MINIDOKA PROJECT.

On the Yuma project, Arizona-California, the Yuma Valley, which lies in Arizona, has been placed under public notice, but the payments have been contested by the water users' association. The Yuma Valley is exceedingly prosperous, having a gross yield for the year 1919 of \$134 per acre, exclusive of live-stock increase. A successful sale was held in December, 1919, of a portion of the lands on the Yuma Mesa, which will be irrigated under the provisions of a special act of Congress, with water pumped from the main canal south of the city of Yuma. A contract has been executed with the Imperial irrigation district to connect its system with Laguna Dam and provide better security for its water supply.

The Orland project in California is regarded as the first unit of a comprehensive project for the development of the Sacramento Valley. It, however, stands alone as a self-supporting project, with an ample water supply from Stony Creek, a tributary of Sacramento River, and has been practically completed. Public notice on this project was issued in 1916, and all payments are made promptly when they fall due by the association as a whole. Thus all the annoyance, expense, and risk of delinquency are voluntarily shouldered by the water users' association, which has shown a commendable spirit of cooperation from the first. The project is prosperous and constantly growing in development. The only construction work in progress is a small amount of permanent canal lining, which was provided for in the current public notice, and which is necessary for checking the seepage from the canals constructed in coarse material.

The Grand Valley project in Colorado is delivering water to a portion of the land which has been opened to entry and occupied by settlers. The agricultural operations are gradually extending and results are encouraging. The physical conditions in this valley are difficult on account of the seamy shale which occurs on the canal system and which has required a large amount of maintenance and betterment work to render the canals tight. Aside from these difficulties the works are operating in a very satisfactory manner.

The Uncompahgre project, Colorado, is being operated by the United States under contract with the water users' association upon the payment of the cost of such operation by the association. The contract provides that the operation may be turned over to the water users' association whenever they so elect, and this is being consummated. The existing contract provides for the operation at cost for a period of five years, at the end of which period the project is to be opened under public notice unless further extension is made by the Secretary of the Interior. At that time, according to the contract, the construction repayments will begin. The construction of the project is completed so far as the plans of the Government have been made, but the distribution systems, which remain in the hands of the

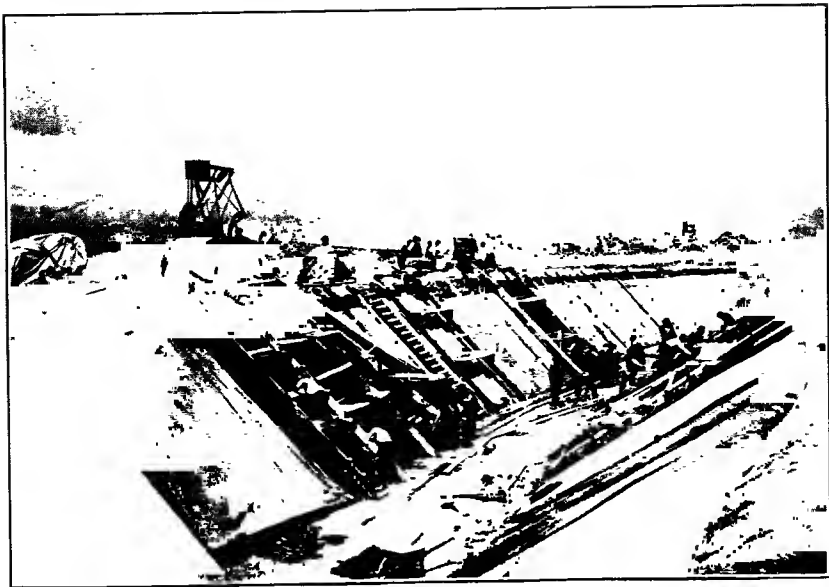
irrigators, are very unsatisfactory and should be enlarged and improved. The cultivation of the lands is gradually extending and slow improvement is being made in the use of water, which is very wastefully applied to the lands. Efforts are being made to introduce the rotation system and to charge for water on an acre-foot basis, which will be necessary before early practice in the economy of water can be hoped for. The excessive application of water is manifested by a rising water table and the destruction of the fertility of some of the land. Agriculture in general is successful, and the settlers are prosperous.

The Boise project in Idaho includes the Arrowrock and Deer Flat Reservoirs, which have been completed, and a canal system, which now delivers water to the main body of the project. Contemplated extensions will be made gradually to conform to better practices regarding the use of water which is sufficient for irrigating about 40,000 additional acres of land if used with reasonable economy. Public notice was issued in 1917 announcing the charges on the completed portion of the project, but the water users brought suit to escape a portion of the repayment, and this has been tried in the United States court. A preliminary opinion has been handed down by the court, which holds that the full cost of the project must be paid by the beneficiaries, but withholds decision upon several points of detail.

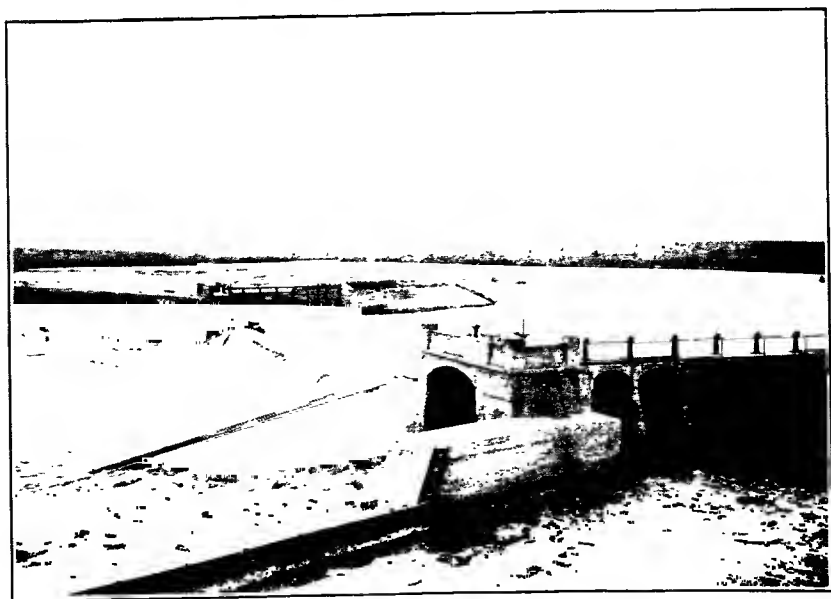
In addition to the main project, the United States, under 11 special contracts, delivers storage water to about 150,000 acres of lands that are served by independent systems. The current year has been one of exceptional drouth, and it was preceded also by a very dry year. It is the general opinion, as expressed by the water users and the local press, that the benefits the past season from the storage works constructed by the Government have been greater than the total cost of those works in the increased product upon the lands served by stored water which would have been without water except for these works. The project as a whole is very productive and successful.

The Minidoka project in Idaho as originally planned has been completed, but several extensions are possible and desirable. The project is in two portions—that which is served with irrigation water by gravity has been formed into an irrigation district which operates the canal system serving it under contract with the United States; the pumping unit on the south side of the river is operated by the United States. The results of irrigation in this region are very striking and exceptionally successful.

The Huntley project in Montana is practically completed, and is one of the most successful and thickly settled projects of the service. Drainage work is in progress and some enlargement of a portion of



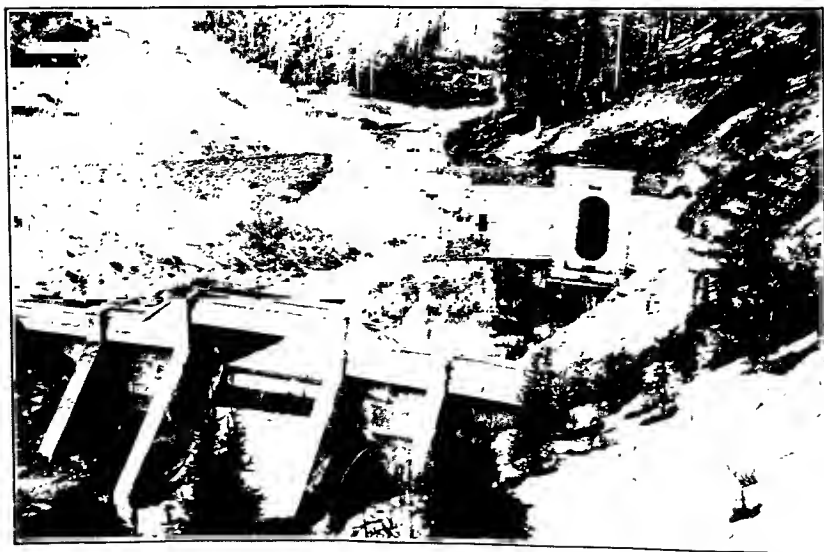
1. PLACING CONCRETE LINING, SUN RIVER SLOPE CANAL, SUN RIVER PROJECT.



2. WALEN DIVERSION DAM, NORTH PLATTE PROJECT.



1. DIVERSION DAM, SPANISH FORK RIVER, STRAWBERRY VALLEY PROJECT.



2. WEIR AND OUTLET PORTAL, STRAWBERRY TUNNEL, STRAWBERRY VALLEY PROJECT.

the delivery system is also being made. Construction payments upon the lands served are being regularly made.

In the Milk River Valley, Mont., water is being delivered through a canal leading from St. Mary River, which diverts that river just below St. Mary Lake. By a treaty arrangement with Canada the waters of the St. Mary are divided on an agreed basis, and this water is being used very completely. The recent demand for irrigation water, on account of the excessive dryness of successive seasons, has been greater than ever before. The water is all used on a rental basis, partly through the works of the service and partly delivered to canal systems of private or cooperative companies.

On the Sun River project, Montana, the original unit on the south side of Sun River is being operated as usual. On the north side of the river, where many of the settlers were attempting to secure title to their homesteads without the liability for irrigation water which is included in their filing papers, a series of three dry years in succession has shown that dry farming is not profitable and has revived the demand for irrigation water. Difficulties with the canal systems have been encountered on account of the unfavorable material with which they were constructed, but it is possible this year to deliver water to about 25,000 acres, and a considerable portion of this is being served on a rental basis.

The Lower Yellowstone project, in Montana and North Dakota, has been operated for years on a rental basis, with only a small fraction of the lands irrigated. The neighboring lands have been for years farmed without irrigation, and though the returns from dry farming have always been less than under irrigation, the temptation to avoid the expense of water service has been so great that the project has not yet been placed on a paying basis. A series of dry years, however, has increased the demand for water, and steps have been taken to form an irrigation district and arrange for permanent water rights for the lands to be included. Appropriate laws have been passed by both States and the prospect is good for the success of the project. The demand for water of this project has been more than twice as great this year as in any previous year, and good crops are reported.

The North Platte project, in Nebraska and Wyoming, is one of the largest as well as one of the most successful of the reclamation projects. The Interstate unit, on the north side of the river, most of which is under public notice, is largely under cultivation, and improvement is steadily extending. Drainage is being constructed and considerable areas are yet to be relieved. On the south side of the river the main or Fort Laramie Canal and its lateral system are under construction and water is being delivered under rental con-

tracts. This is the region of most rapid development of anything in the service.

The Newlands (formerly Truckee-Carson) project, in Nevada, has been somewhat held back in past years on account of difficulties in the way of forming an irrigation district to provide funds for necessary drainage work. Recent State legislation has relieved these difficulties and the irrigation district recently formed has taken up the drainage situation energetically. Another difficulty has been the lack of storage for the lands on the upper part of the system, but legal and other obstacles have been thrown in the way of a proper regulation of Lake Tahoe, the only available reservoir site of consequence which can serve this region. The main canals for using water have been built, but storage works are still necessary. Pending their development, no further extension is feasible.

The Carlsbad project in New Mexico is gradually increasing its cultivated area, and is in a prosperous condition. Some drainage is still to be accomplished, but the water supply is ample and results are satisfactory.

The Rio Grande project in New Mexico and Texas is being operated on a rental basis. Nearly one-half of the land is in cultivation and is being served by storage water from the Elephant Butte Reservoir. The flat topography of the valley, the peculiar fineness of the soil, and the very wasteful use of water in the past have brought up the water table over most of the valley and much of the land has been injured. An extensive drainage system is being installed and is successful so far as constructed. Its prosecution, however, is greatly hampered by the lack of sufficient funds. The lateral system which has been operated for many years by the local association of irrigators is very inadequate and inefficient, and the water is wastefully used. At the instance of the water users the various works are being gradually turned over to the Government and are being rebuilt and put in shape for efficient service. This will to some extent remedy the threatening condition of the rising water table and is necessary for the success of the drainage system planned. The progress along this line has been successful so far, but not very extensive.

The North Dakota pumping project, which has not been operated for several years owing to failure of the lands benefited to make payment therefor, has been formed into an irrigation district and a contract made with the Secretary of the Interior assuring its operation and the payment for the cost thereof. It was operated in 1919 with results that under the conditions existing may be considered very good.

The Umatilla project in Oregon has always been bothered by drifting sand and in some restricted localities by an extremely coarse sub-

soil which allows the rapid escape of irrigation water and the leaching of soil. These difficulties are being overcome to some extent, and progress in cultivation is steady and encouraging. Urgent requests have been made for the Government to enlarge the project by taking over some of the private canals which have insufficient water supply and constructing a reservoir to serve them. This can not be undertaken without additional funds.

The Klamath project in Oregon and California is being gradually extended as the waters of Tule Lake recede owing to the diversion of the supply through the Government works. Drainage works are in progress and have been successful so far as constructed. The irrigated land is productive and the settlers generally prosperous.

The Belle Fourche project in South Dakota is growing in production and prosperity. In some localities the water table is rising and drainage works should be installed, but arrangements have not yet been made for the repayment of the cost. A small amount of the land under the feed canal and not served from the Owl Creek Reservoir suffers from water shortage in some years, and plans are under way for providing a small storage reservoir to serve these lands.

On the Strawberry Valley project in Utah the principal work constructed by the Government is a storage reservoir in Strawberry Valley on the headwaters of the Duchesne River and the diversion of its waters through a long tunnel to the westward slope of the Wasatch Range, where the water is diverted from the Spanish Fork River and an irrigation system constructed. This system is being operated by the irrigators under special contract, and payments of construction charges are being regularly made. In many instances canal systems already in existence are being operated by associations which have made arrangements for storage water from the Strawberry Valley Reservoir and are operating their own canal systems. There are still some water rights in the Strawberry Reservoir for sale.

Three extremely dry years—1917, 1918, and 1919—throughout a large portion of the West have broken all records for drought, and thousands of live stock and many private irrigation projects have suffered for lack of water. Dry farming has generally been a failure throughout these regions.

The Reclamation Service experienced serious water shortage on one project—the Okanogan project in northern Washington—in 1918, and while there was some shortage also in 1919 it was not so great. Pumping plants were installed at Salmon Lake and Duck Lake to supplement the storage reservoirs, which did not entirely fill. The additional pumping capacity and the enlargement of the reservoir hold-over capacity are the remedies being carried out.

The Yakima project in Washington includes a large system of storage reservoirs and two canal systems, known as the Sunnyside unit and the Tieton unit. The project as a whole is very productive and prosperous, and strong pressure is being made to secure the construction of more storage, the extension of existing canal systems, and the construction of new canals from the Yakima River and its tributaries. The excellent results obtained show that this would be a wise development. The Yakima project as a whole is one of the foremost in general prosperity and in returning the cost of this construction.

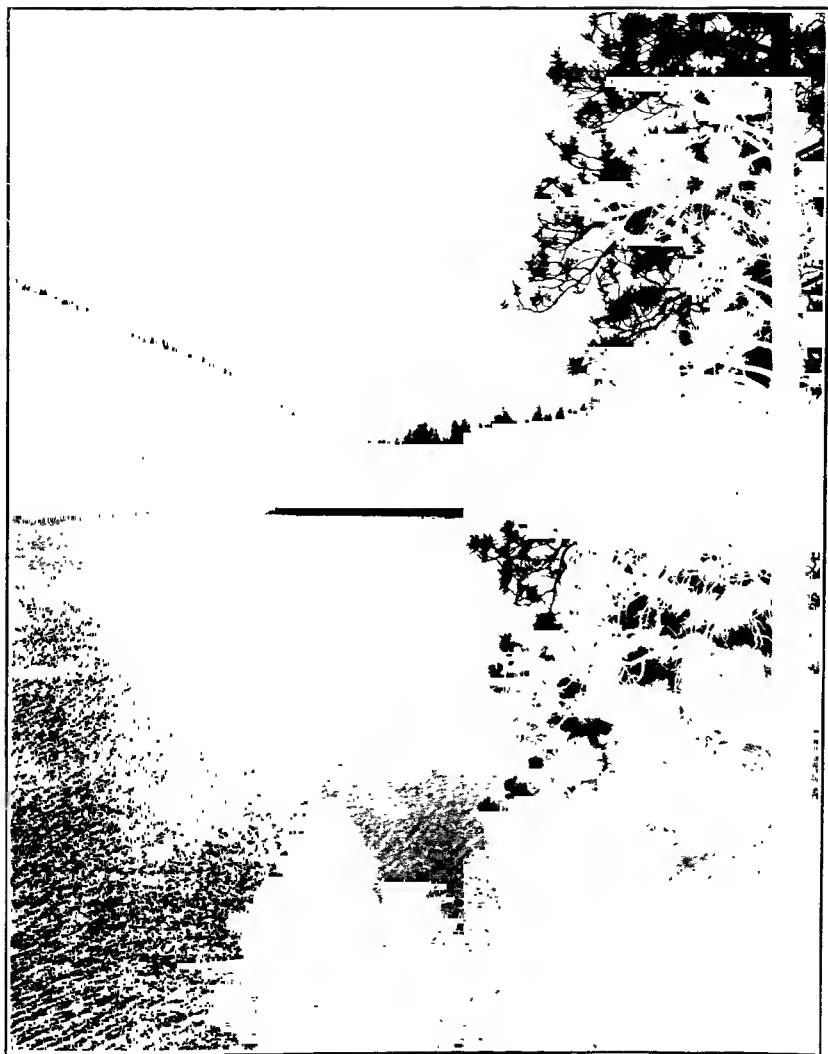
The Shoshone project in Wyoming is being gradually extended by additions to the canal and lateral systems on the north side of the Shoshone River. The drainage system, which has been largely completed and has been very successful, is also being extended under contract with the water users in accordance with law. The lands are very productive and the project very prosperous. Preparations are being made for the construction of an additional unit on the south side of the Shoshone River, for which ample storage capacity has been provided in the Shoshone Reservoir.

The value of the agricultural products exclusive of live stock produced by the Government reclamation projects during the season of 1919, amounting to nearly \$89,000,000, has been over half of the net cost of construction of all of the projects during the last 17 years. On some of the projects the production has exceeded the total construction cost. The results in the extension of agriculture and of homemaking have justified the expectations of the advocates of this activity and argue strongly for its extension.

CROPS.

All agricultural statistics are now dominated by the effects of the World War, and this is strikingly shown by a comparison of the table of irrigation and crop results presented herewith for 1919 with that for 1914 published in the Smithsonian Report for 1915 (p. 473).

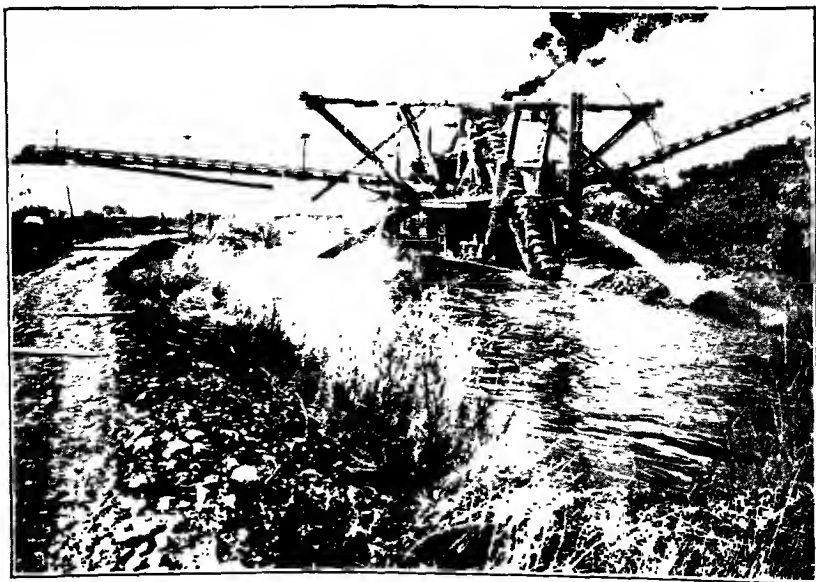
For all projects the crop report for 1919 shows a gross value of \$89,000,000, or an average of \$80 for each of the 1,113,000 acres cropped. Alfalfa continues as the great basic crop, occupying 38 per cent of the crop area and furnishing nearly one-third of the total crop value. Cotton, while grown on only the four southernmost projects, brought in returns of over \$20,000,000 in 1919. The following table presents statistics relating to crop production as collected by Government employees on the Reclamation Service projects. Figures for crops from over 1,000,000 acres of lands on private projects



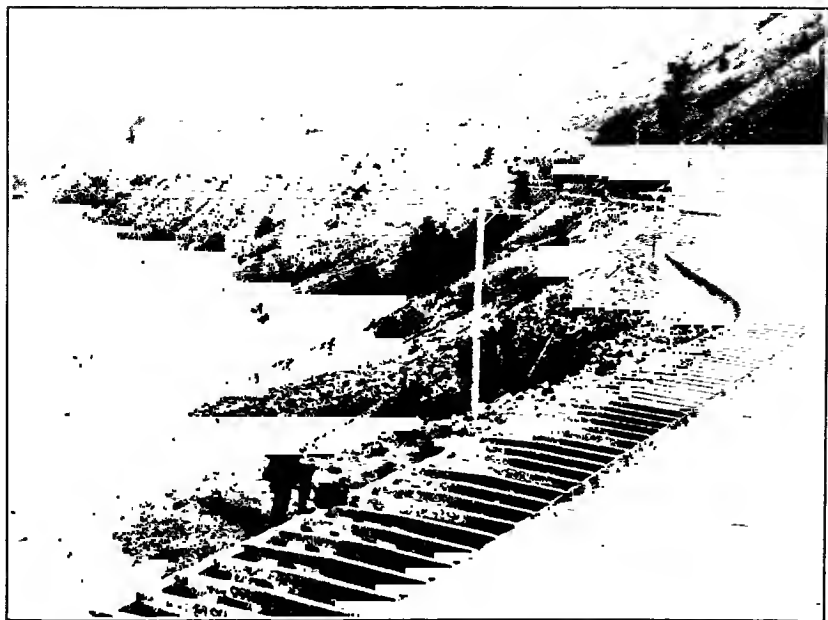
CONCONULLY RESERVOIR, OKANOGAN PROJECT.



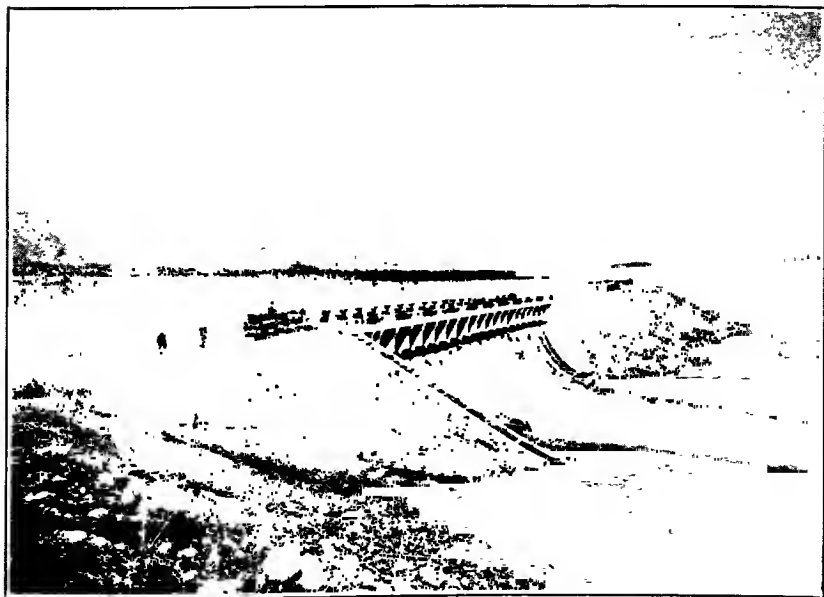
1. IRRIGATING AN ORCHARD, YAKIMA PROJECT.



2. FLOATING DREDGE ENLARGING SUNNYSIDE MAIN CANAL, YAKIMA PROJECT.



1. TIETON MAIN CANAL, YAKIMA PROJECT.



2. JACKSON LAKE DAM, WYOMING.



ON THE HEADWATERS OF THE SNAKE RIVER, WYOMING.

supplied with stored water from reservoirs constructed by the Reclamation Service show crops valued at \$64,000,000 more.

Irrigation and crop results, Government reclamation projects, 1919.

State and project.	Lands on projects proper covered by crop census.				
	Irrigable acreage. ¹	Irrigated acreage.	Cropped acreage. ²	Crop value.	
				Total	Per acre.
Arizona:					
Salt River.....	212,966	205,064	188,232	\$23,768,682	\$126.27
Arizona-California:					
Yuma.....	70,000	53,284	52,324	7,012,209	134.00
California:					
Orland.....	20,533	15,203	12,409	892,259	71.90
Colorado:					
Grand Valley.....	35,000	10,049	8,899	570,629	64.12
Uncompahgre.....	100,000	60,906	59,746	3,391,456	56.76
Idaho:					
Boise.....	123,772	103,782	99,093	6,254,904	63.12
King Hill ⁴	14,500	4,993	3,959	219,246	55.39
Minidoka—					
Gravity unit.....	72,589	59,259	57,068	3,364,049	58.95
Pumping unit.....	48,976	45,000	41,780	2,562,210	61.32
Montana					
Huntley.....	31,265	19,310	19,310	948,968	49.14
Milk River ⁷	67,000	25,485	24,099	600,864	24.93
Sun River—					
Fort Shaw division ⁸	14,023	8,186	8,292	348,620	42.07
Greenfields division No. 1.....	26,000	3,310	2,902	23,816	8.20
Montana-North Dakota:					
Lower Yellowstone.....	42,167	21,300	21,289	869,117	40.82
Nebraska-Wyoming:					
North Platte—					
Interstate unit.....	111,915	88,990	85,690	3,916,736	45.71
N. P. C. & Co. lands.....	17,800	10,428	10,352	363,718	35.13
Fort Laramie.....	12,132	6,258	6,258	143,367	22.91
Nevada:					
Newlands.....	65,809	44,324	43,296	1,840,650	56.59
New Mexico:					
Carlsbad.....	24,991	20,363	18,753	1,988,546	106.04
New Mexico-Texas:					
Rio Grande.....	107,000	77,033	72,170	3,825,107	53.00

¹ Data are for calendar year (irrigation season), except on Salt River project, where data are for corresponding "agricultural year," October, 1918, to November, 1919.

² Area Reclamation Service was prepared to supply water.

³ Irrigated or cropland, including small areas in dry farming.

⁴ Includes so-called "vacant" land, on some of which

⁵ Includes 3,000 acres of land, including houses, lots, corrals, etc.

⁶ Data furnished by the project, which was built under private auspices.

⁷ The United States has undertaken its reconstruction; operation and maintenance are handled by the district.

⁸ Crop reports covered an additional area of 7,287 acres cropped by dry farming, producing crops worth

\$39,150, or \$5.37 per acre.

⁹ Above figures are for 196 irrigated farms, which included small tracts farmed without irrigation. In

addition two units farmed "dry" reported 1,200 acres of land, valued at \$120.

¹⁰ Limited by water available. Figure for 1919 is 1,200 acres of land, valued at \$120.

¹¹ For crops in full production, excluding 1,200 acres of land, valued at \$120.

¹² For crops in full production. For all crops, \$42.50.

Irrigation and crop results, Government reclamation projects, 1919—Continued.

State and project.	Lands on projects proper covered by crop census.				
	Irrigable acreage.	Irrigated acreage.	Cropped acreage.	Crop value.	
				Total.	Per acre.
North Dakota:					
North Dakota pumping.....	12,238	2,446	2,370	\$69,990	\$29.53
Oregon:					
Umatilla.....	24,501	10,533	8,464	633,380	74.83
Oregon-California:					
Klamath.....	50,000	37,881	32,688	859,805	26.30
South Dakota:					
Belle Fourche.....	82,634	56,255	56,255	1,962,683	34.89
Utah:					
Strawberry Valley.....	50,000	33,123	29,255	1,973,059	67.50
Washington:					
Okanogan.....	10,099	5,849	5,314	1,951,475	367.23
Yakima—					
Sunnyside unit.....	100,130	90,000	75,856	12,678,247	167.07
Tieton unit.....	32,000	27,000	26,300	4,053,163	154.10
Wyoming:					
Shoshone—					
Garland unit.....	56,119	34,697	34,183	1,708,644	49.93
Frannie unit.....		6,944	6,833	178,333	26.10
Total.....	1,636,159	1,187,255	1,113,469	88,974,137	79.88

INVESTIGATION OF SWAMP AND CUT-OVER LANDS.

In the appropriation for the United States Reclamation Service for the fiscal year 1919, the Congress made the following provision for the investigation of swamp and cut-over lands:

For an investigation to be made by the Director of the Reclamation Service of the reclamation by drainage of lands outside existing reclamation projects and of the reclamation and preparation for cultivation of cut-over timberlands in any of the States of the United States, including personal services in the District of Columbia and elsewhere, purchase, maintenance, repair, hire, and operation of motor-propelled or horse-drawn passenger vehicles, and for all other expenses, there is appropriated, out of any money in the Treasury not otherwise appropriated, \$100,000.

In undertaking this investigation, the work fell naturally into three divisions, one comprising the States north of the Ohio River and east of the Missouri, another including the Southern States, and a third taking in the States lying partly or wholly west of the hundredth meridian.

Any classification of the swamp and cut-over lands of the country must be exceedingly rough and general, as, owing to the nature of the case, two different authorities, however careful and skillful, will probably differ widely in results if these are independently obtained.

This is due to the difficulty of setting any definite bounds to any class which may be adopted, owing to the following reasons:

Lands needing drainage can not be absolutely delimited owing to the varying necessities of drainage at different times of year and in different years owing to change of season and mutations of climate. The area is also constantly changing by improvement of natural outlets or the construction of artificial drains, and where the ground water stands too high for one character of production it may be suitable for another. Where the ground water is too high for successful agriculture in a wet year it may in a dry year for the same reason be superior to other lands in the vicinity with low water table.

Many areas of cut-over lands also require drainage, and to be made agricultural must be not only drained but cleared of brush and stumps. Large areas of cut-over lands are too rough or too rocky for agriculture and should be allowed to reforest themselves; but opinions will differ on this point, and any useful classification must take these facts into consideration.

Cut-over lands are even more difficult to define than those needing drainage. The majority of existing forests have at some time or other been cut over, and often the land has been actually in cultivation and practically denuded of trees. The abandonment of fields or the neglect of the cut-over areas permits the growth of young timber, which is sometimes useful and sometimes of little value. Thus, by one definition, any land that has ever been timbered and cleared may be regarded as cut-over land, although in a high state of cultivation. This is obviously not the usual or accepted meaning of the term. If the fields have been abandoned and young brush has started up, it may in some cases be reduced to cultivation again at moderate expense any time in the first few years, but this expense may increase as the timber grows and clearing becomes more expensive. After the lapse of 50 or 60 years the timber may become merchantable and the land, although strictly speaking it has been "cut over," requires extensive clearing to reduce it to cultivation, and may be similar in its essential characteristics to the virgin forest.

Where the merchantable timber has been cut, leaving stumps, young brush, and small trees, it constitutes a typical case of what is known as cut-over land, but as time passes the young trees grow to merchantable size, the stumps gradually decay, and in time this land ceases to be "cut-over" land.

It is thus obvious that different authorities, however careful or skillful, may differ widely in their reports of the actual areas of wet and cut-over lands and still more widely when attempt is made to classify these as agricultural and nonagricultural. For this reason, any statistics on this subject must be regarded with allowance, and should have the term used carefully defined for specific tables.

The distribution of reclaimable agricultural land is very irregular and erratic. The Lake States, the southern Atlantic, and the Gulf States contain vast areas of lands requiring drainage and also timberlands, the majority of which have been at some time or other cut over and a large proportion of which would be suitable for agriculture if properly cleared. It by no means follows that all of such lands should be now or eventually devoted to agriculture.

In many places the swamps and overflow lands serve useful purposes as reservoir sites to diminish the volume and intensity of the floods of the drainage basins in which they occur, and each one should be carefully considered as to the advisability of continuing its services and improving its efficiency for these functions. The regulation of streams is important from many points of view. If our streams could be made to flow with comparative regularity instead of in great flood waves, it would terminate destructive floods that cause such havoc and loss of life. To accomplish this we must carry out gigantic projects, such as those in the Miami conservancy district in Ohio, designed mainly or exclusively to moderate the freshets and regulate the flow of the streams.

The feasibility of such works depends largely upon the existence of suitable reservoir sites.

A good reservoir site is in several respects a topographic rarity. It must ordinarily have a suitably located basin, with a sufficient watershed above, which can be closed and formed into a reservoir by a feasible dam of moderate cost which will form a reservoir of large capacity in order that its usefulness may be commensurate with its cost. Where such favorable reservoir sites exist they may be of great value and may constitute the key to the feasibility of river regulation, and if reclaimed for agriculture and built up with towns, villages, railroads, and other improvements, their cost soon becomes prohibitive, and the only feasible opportunity of river regulation may thus be destroyed. Every scheme for the drainage and reclamation of swamps and low-lying river bottoms should therefore be carefully considered in its relation to the country at large, and especially that below on the streams to which its waters are tributary, and if the proposed reclamation will in fact destroy a good and useful reservoir site, it should not only be avoided but precautions should be taken to prevent the accumulation of improvements which will become obstructions to its utilization for storage purposes. This principle is far more important than usually realized, because we are apt to overlook the need, the rarity, and the essential characteristics of feasible reservoir sites.

Similar precautions are necessary in examining areas of timber or cut-over lands with reference to the wisdom of clearing and devoting them to agriculture. Some lands are so hilly and rocky as

to be unsuited to agriculture, although they may be fairly well adapted to forest growth, and these obviously should be devoted to that purpose; but, though this seems obvious when stated, it should be remembered that the principle has been often and extensively violated. A considerable part of the alleged "abandoned" farm lands in the New England States are lands that should never have been cleared, as they are more suitable for forest growth than for agriculture, and their abandonment has been simply the recognition of their appropriate use.

The existence of rocks and hills is not by any means the only bar to the suitability of such lands for agriculture. The soil may be in some cases unsuitable for various reasons without expensive modification or application of expensive additions.

Even where the soil and topography are highly suitable for agriculture it by no means follows that it would be wise to clear the cut-over lands and devote them to that purpose. There may be other areas in the vicinity just as favorably conditioned where the cost of reclamation would be less or where the timber that must be removed is less valuable and different tracts should hence be considered in the light of their suitability for agriculture in location, topography, soil, and climate, and also the character of growth which clearing would remove in order that the most valuable timber stands may be allowed to mature.

We should never forget that we will always need forests and wood lots to complete the prosperous community, and it is just as important to consider and provide for this need in the most efficient and economical manner as it is to provide for any other community needs. In view of the above it is obvious that only a small fraction of the forested areas which are seen on the general map could be wisely reduced to cultivation at the present time, or even within the next generation. By a wise and skilful discrimination we must select those areas requiring the least expenditure and least destruction to reduce them to cultivation, and must leave uninjured and adequately protected the areas needed for water storage and those most suitable for forest production. This still leaves an ample choice in the States mentioned for all of the reclamation that is likely to be carried out within the next generation, although the rules upon which selection is made must obviously be modified from time to time.

RECLAMATION OF NEGLECTED FARMS.

In some of the States where little or no opportunity exists for the reclamation of arid, wet, or cut-over lands there are still abundant opportunities for development which involves reclamation of other kinds. Many areas exist which have been cultivated and for

lack of proper treatment have become so nearly barren as to be considered exhausted and unprofitable for agriculture, and are wholly or partly abandoned. Some of these have improved by the interval of noncultivation, but the major portion require the addition of some of the elements of plant food or the elimination of deleterious qualities by proper treatment.

The majority of eastern soils, for example, are more or less acid and require the application of lime or other antidotes to neutralize the acidity. They generally require also the addition of nitrogen, which can be accomplished by the proper growth of legumes to be incorporated with the soil by plowing under. Some also require the addition of phosphates or of potash, and the cases are numerous where such reclamation as that described is as appropriate and as profitable as reclamation of other kinds in other regions. In some cases large areas have been gradually concentrated in single ownerships, and the system of tenantry which has followed does not produce the best results but leads to the neglect and deterioration of the soil until its cultivation yields little profit. Where such areas can be acquired and cut up into homes they may be restored by proper tillage methods and the addition of nitrogen or other plant food until they are capable of constituting thickly settled and prosperous colonies. It is often found that large ownerships and tenant farming are the accompaniments if not the causes of neglect and partial or entire abandonment of agriculture. Reclamation from such conditions is as wise and as necessary as any other mode of development.

The purpose of the appropriation for these investigations was understood to be the feasibility of preparing farms for settlement by returned soldiers under a planned rural development such as has been carried out in Australia and many European countries with benefit both to the settler and the community at large. Investigations have shown that many of the so-called abandoned or neglected farms in the Eastern and Middle States can be rehabilitated by proper culture with more or less clearing, draining, and leveling and the addition of lime or other needed constituents of soil.

The investigations along this line were necessarily of a most preliminary nature, as one of the principal facts to be developed is the price of land, and no actual negotiations could be carried on to ascertain this in the absence of authority and funds for the purchase. The information, therefore, is of a general nature, but indicates that such opportunities of an attractive character can be found in practically all the Northern, Eastern, and Middle States, where improved farms can often be purchased at but little increase over the present value of improvements, and by some or all of the methods of reclama-

tion above mentioned can be made suitable for colonization at reasonable price.

Those same States also contain many large areas in private ownership, but held at very moderate prices, which belong in the category of wet and cut-over lands, requiring drainage in some cases and clearing in nearly all cases. In some instances they have been under cultivation in the past, but have been abandoned for many years, or used for pasture only, and allowed to grow up in brush, which will require clearing. Most of such lands also require the addition of lime, the building of roads, and the opening of drainage outlets to permit the escape of excessive rainfall.

NORTHERN DIVISION.

The northern division comprises the area east of the Missouri River and north of the Ohio. The opportunities for settlement are abundant in most of these States, and especially so in the Lake States—Michigan, Wisconsin, and Minnesota—where vast areas of cut-over lands and lands needing drainage are found, and some of them were examined in detail.

In several of the States of the Mississippi Valley where agricultural conditions are excellent the development has been so complete that only small areas of undeveloped lands have been found. Some of these are cut-over regions, some are naturally wet places needing drainage, and some are overflow lands which require levee protection and drainage works. These States, however, all contain considerable areas in large ownerships, farmed by tenants, where results are unsatisfactory and are growing worse. Many of these offer favorable opportunities for soldier settlements which will be nearly as beneficial to the country at large and as favorable for the soldier settlements as the reclaimed lands in other States. With proper local cooperation there is no doubt that favorable colonies can be established in all the States.

In New York and Pennsylvania are considerable areas of good cut-over lands, some of which are adaptable to agriculture and very favorably situated for settlements. The convenience of transportation and the abundance of good markets near at hand give these regions important advantages over some others, and in New York are many areas requiring drainage which apparently will afford favorable locations for colonies.

New England presents the extreme case of local need for agriculture. The present agricultural production of New England is but a fraction of what it was half a century ago, while the growth of population and of manufacturing industries makes a market which

draws more and more for subsistence upon the Mississippi Valley and the Far West. The development of agriculture here is of first importance in sustaining the manufacturing industries in the face of the necessity of transporting their food and raw materials. Many excellent opportunities for the development of cut-over lands, the drainage of wet lands, and especially the rehabilitation, fertilization, and building up of areas which have in the past been farmed but are now wholly or partially neglected are offered in this section.

The decline of New England agriculture has been due in general to the demand of its growing manufactures for the necessary labor and the competition of cheap, fertile, and extensive agricultural areas of the Mississippi Valley and the great West. These lands are no longer cheap, and the growth of the Middle West is to a large extent absorbing the product of the western farms, so that New England must enter into active competition for its food supply under the handicap of costly transportation. This condition has reversed the influence which led to the decline of New England agriculture, and in providing for its rehabilitation the soldier settlement program affords the opportunity of doing this and at the same time keeping at home the thousands of soldiers who enlisted from these centers of population.

SOUTHERN DIVISION.

In the Southern States opportunities for colonization are of the same three classes. The largest areas are of cut-over lands. In past years small holdings of timberland have been acquired by lumber companies and merchantable timber has been cut and marketed as lumber. Many of these large companies are now operating and are anxious to sell the cut-over land usually at low prices. In some cases drainage would be required and in others drainage should be assisted by opening and straightening surface outlets to permit the ready escape of excessive rainfall. In some of the richest localities where land can be had very cheaply, one of the principal drawbacks which must be overcome is the elimination of the swarms of mosquitoes, which will require careful surface drainage and elimination of stagnant water. Also the clearing of luxuriant vegetation which springs up after the timber is removed. Such areas can only be successfully colonized in tracts of considerable size, as it is impracticable to carry out mosquito extermination on a small scale. In many of the Southern States, especially the border States, are to be found extensive areas which have been either abandoned or neglected since the Civil War and are of similar character to those described in New England. They can generally be purchased cheaply and rendered fertile by clearing and the addition of lime and nitrates.

WESTERN DIVISION.

The eastern tier of the States comprised in this division—the Dakotas, Nebraska, Kansas, Oklahoma, and Texas—have considerable areas of humid land in which drainage is frequently needed and irrigation is not needed. Lands can be found in all of these States which are not swampy, but in which a high water table requires that they be drained in order to fit them for other use than pasture or meadow or forest culture. Drainage can in many cases be provided at reasonable cost and where clearing is necessary this also is comparatively inexpensive. Farther west, irrigation projects have been investigated in the past and numerous opportunities of feasible development of this character exist in most of the Western States.

Such reclamation can be applied to public land in Wyoming, Idaho, Washington, Oregon, California, and Arizona. In the other arid States most of the land to be reclaimed is in private ownership.

The areas west of the hundredth meridian present many opportunities for reclamation not only by irrigation but by drainage and by the clearing of cut-over lands, the latter opportunities occurring chiefly in Montana, Idaho, Washington, Oregon, and California. Only a small percentage of these lands, however, are really suitable for reclamation at the present time. East of the mountain ranges the cut-over lands are mainly arid or semiarid and hence require irrigation for successful agriculture. The combination of the cost of irrigation and of the necessary clearing and leveling of the lands is usually prohibitive even in the cases where irrigation is feasible at all, and in such cases it is usually best to encourage the reforestation of the lands by protecting the young growth from fire. Considerable areas of semiarid land may by scientific methods be successfully cultivated without irrigation, but as the results are more or less precarious, the values for such agricultural use are usually not high and may exceed the cost of clearing.

There are cases, however, where such reclamation may be wisely carried out. In the extreme Northwest, on the Pacific slope, are large areas of cut-over lands where deep and excellent soil occurs, where the topography is suitable, and where the rainfall is also sufficient for successful farming. Some areas in this region can be profitably and wisely devoted to agriculture, but in a large portion the cost of clearing, owing to the number, size, and character of the stumps that are in the way, would at present values of agricultural land make the enterprise prohibitive, and the land can best be utilized by reforestation. This is true also to some extent in western Oregon and northwestern California. A large portion of the cut-over lands in the Northwest is, of course, unsuitable for agriculture on account of

topography and rocky soil and can best be restored to forest condition.

The great bulk of the land west of the hundredth meridian which is not too high, cold, or rocky for agriculture is arid. Of this arid portion, over 15,000,000 acres have been placed under irrigation by private or public enterprise, and in carrying out this work, of course, the more favorable opportunities for such irrigation have been developed. It will still be possible to add many million acres to the irrigated area and perhaps to double the area now irrigated, but this must generally be done at high cost, as the cheap opportunities have been long since exhausted. There are remaining, however, many areas which can be irrigated within feasible costs and will develop values far in excess of the necessary expenditures. They will furnish healthful homes for settlers and will supply agricultural products and food resources in proximity to great mining and grazing resources, which will be made more valuable thereby. There is much room for wise and profitable activity in this line in most of the Western States, but the total areas that can be thus reclaimed are much less than those offering opportunities in the States farther east.

The following table summarizes the results of the investigations made in the western division:

Projects and extensions of projects investigated by the Reclamation Service in the Western States.

State and project.	Irrigable acreage.			Mean altitude.	Mean rainfall.	Probable cost. ¹	Readiness for construction.
	Public.	Private.	State.				
Arizona:				<i>Feet.</i>	<i>Inches.</i>		
San Carlos.....	2 40,000	30,000	.....	1,500	10	\$13,600,000	Not ready.
California:							
Imperial Valley.....	400,000	.....	.....	—200	3½	52,000,000	Ready.
Palo Verde.....	.....	40,000	.....	250	3	5,000,000	Not ready.
Turlock-Modesto.....	.....	260,000	.....	95	12	5,000,000	Do.
Kings River.....	.....	400,000	.....	225	10	12,000,000	Do.
Orland extension.....	.....	30,000	.....	245	18	2,500,000	Ready.
Iron Canyon.....	.....	225,000	.....	230	17	30,000,000	Not ready.
Cuyamaca Water Co.....	.....	2 2,750	.....	400	12	(*)	Do.
Volcan Land & Water Co.....	.....	2 24,600	.....	500	15	(*)	Do.
Jess Valley.....	.....	2 17,800	.....	4,400	12½	1,100,000	Do.
Colorado:							
Grand Valley.....	15,000	15,000	.....	4,825	8	600,000	Ready.
Grand Valley drainage.....	.....	30,000	.....	4,650	8	1,200,000	Do.
Orchard Mesa.....	.....	9,700	.....	4,750	8	800,000	Do.
Uncompahgre.....	10,000	37,000	.....	5,500	9½	500,000	Do.

¹ These estimates must be considered as merely preliminary and subject to change.

² Indian.

³ Lands not classified; classification shown is assumed.

⁴ No estimate.

Projects and extensions of projects investigated by the Reclamation Service in the Western States—Continued.

State and project.	Irrigable acreage.			Mean altitude.	Mean rainfall.	Probable cost.	Readiness for construction.
	Public.	Private.	State.				
Colorado—Continued.				<i>Feet.</i>	<i>Inches.</i>		
Montezuma.....		42,000	8,000	5,000	12	\$3,500,000	Not ready.
San Luis Valley drainage.....		400,000		7,600	7	10,000,000	Ready.
Idaho:							
Hillcrest.....	3,000	10,000	1,000	2,800	13	700,000	Do.
Black Canyon.....	3,000	35,000	1,000	2,400	12	2,000,000	Do.
Minidoka.....	95,500	250	6,750	4,300	12½	15,000,000	Not ready.
Gem District.....		27,000		2,350	12	750,000	Ready.
Lake Walcott.....	2,480		20	4,400	12½	215,000	Do.
American Falls Reservoir.....	* 33,000	33,000		4,300		12,000,000	Not ready.
Island Park Reservoir.....	* 10,700	5,000		6,250	15	4,000,000	Ready.
Boise Valley drainage.....		30,000		2,500	12½	600,000	Do.
Payette Valley drainage.....		10,000		2,250	11½	180,000	Do.
Sbelley Canal.....	* 100,000			4,600	14	(*)	Not ready.
Bruneau.....	* 400,000			4,200	11	(*)	Do.
Mountain Home.....	* 400,000			4,000	13	(*)	Do.
North Side Twin Falls.....	* 50,000			4,000	12	(*)	Do.
North Side pumping.....	* 115,000			4,000	12	(*)	Do.
Hansen Butte.....	* 24,000			4,000	12	(*)	Do.
Wood River.....	* 40,000			4,200	14	(*)	Do.
Dubois.....	* 200,000			4,800	15	(*)	Do.
Idaho Falls pumping.....	* 100,000			4,700	15	(*)	Do.
Montana:							
Milk River—							
Chinook Division.....		50,000					Do.
Beaver Creek Division.....	10,000		708	2,200	14	1,700,000	Ready.
Cut Bank.....	* 25,000	11,000		3,800	13	1,200,000	Not ready.
Sun River.....	35,000	30,000		4,100	11	4,000,000	Ready.
Bitter Root.....		30,000		3,450	11	1,500,000	Not ready.
Judith Basin.....		36,500		4,300	17	2,505,000	Do.
Missoula-Huson.....		8,100		3,100	16	313,000	Do.
Helena Flats.....		15,000		2,800	16	450,000	Do.
Nebraska:							
North Platte extensions.....	65,000	88,000	10,000	4,100	13	9,000,000	Ready.
Dawson County.....		45,000		2,700	22	2,500,000	Not ready.
Farmers' Canal.....		50,000		2,600	22	2,000,000	Do.
Nevada:							
Upper Carson.....	3,500	35,500		4,500	12	2,000,000	Ready.
Pyramid Lake.....	15,000	1,000		4,000	4	1,200,000	Do.
Humboldt River.....		* 90,000		4,200	9	9,000,000	Not ready.

* These estimates must be considered as merely preliminary and subject to change.

* Indian.

* Lands not classified; classification shown is assumed.

* No estimate.

* In Fort Hall Indian Reservation.

* In Targhee National Forest.

*Projects and extensions of projects investigated by the Reclamation Service
in the Western States—Continued.*

State and project.	Irrigable acreage.			Mean altitnde.	Mean rainfall.	Probable cost.	Readiness for construction.
	Public.	Private.	State.				
New Mexico:				<i>Feet.</i>	<i>Inches.</i>		
San Juan	† 125,000	-----	-----	5,200	8	(*)	Not ready.
Middle Rio Grande drainage	-----	100,000	-----	4,800	7½	\$5,500,000	Ready.
Oregon:							
Klamath pumping units	-----	23,000	-----	4,100	12	1,200,000	Do.
Langell Valley	-----	17,000	-----	4,200	12½	1,000,000	Do.
Tule Lake	17,000	-----	-----	4,000	14	1,250,000	Do.
Rogue River	-----	30,000	-----	1,600	20	2,000,000	Not ready.
Greater Umatilla	3,500	{ 12,000 * 3,050 }	-----	500	8½	3,100,000	Do.
Owyhee	6,000	17,000	-----	2,200	10	2,100,000	Do.
Deschutes	-----	200,000	-----	3,200	9	12,000,000	Ready.
Lower Powder River ...	* 38,000	25,000	-----	3,000	13	7,000,000	Not ready.
Horsefly storage	2,000	1,400	-----	4,100	12½	300,000	Do.
South Dakota:							
Belle Fourche extension.	11,000	22,300	3,917	2,800	14½	700,000	Do.
Texas:							
Tornilla-Fort Hancock unit	-----	27,000	-----	3,500	8	1,200,000	Do.
Lower Rio Grande	-----	600,000	-----	80	26	(*)	Do.
Utah:							
Castle Peak	70,000	-----	-----	5,200	9	7,000,000	Do.
Price River	30,000	-----	-----	5,500	12	(*)	Do.
Dixie	30,000	-----	-----	3,000	8½	(*)	Do.
Utah Valley drainage	-----	30,000	-----	4,500	18	1,000,000	Do.
East Juab County	-----	* 30,000	-----	5,000	13	5,000,000	Do.
Washington:							
Yakima High line	13,600	130,000	6,000	1,000	7	20,000,000	Do.
Kittitas	5,000	62,500	2,500	1,800	9½	8,500,000	Ready.
Methow-Okanogan	-----	* 42,000	-----	1,000	12	(*)	Not ready.
Kennewick irrigation district	6,400	27,500	1,100	600	7	6,125,000	Do.
Wyoming:							
Frankie extension	35,000	1,000	1,800	4,200	6	500,000	Ready.
Heart Mountain unit ...	34,100	1,500	3,200	4,900	6	3,300,000	Not ready.
Willwood unit	14,700	320	600	4,300	6	900,000	Ready.
Oregon Basin	68,000	-----	-----	4,500	6	(*)	Not ready.

† These estimates must be considered as merely preliminary and subject to change.

* Lands not classified; classification shown is assumed.

† No estimate.

† In Navajo Indian Reservation.

* Railroad.

* 17,000 withdrawn under Carey Act.



RICHARD RATHBUN.¹

By MARCUS BENJAMIN.

[With 1 plate.]

American science has lost one of its distinguished authorities on invertebrate zoology, and the United States National Museum its honored chief by the death of Richard Rathbun in the city of Washington early on the morning of July 16, 1918.

Richard Rathbun was born in Buffalo, New York, on January 25, 1852, and there studied in the public schools until he reached the age of 15 years, when he entered the service of a firm of contractors, with which he remained for 4 years, acquiring a thorough knowledge of business methods, that was of special value to him during his later years.

At that time, attracted by the specimens of fossils that abound in western New York, he began the study of paleontology to which he assiduously devoted his evenings and holidays. The collection in the museum of the Buffalo Society of Natural Sciences was made by him and he was appointed curator of that subject with charge of its collections by the society.

In 1871, he met Charles Fred. Hartt, then professor of geology at Cornell University and a pupil of the elder Agassiz, who persuaded him to give up business pursuits and devote himself to science. Young Rathbun accordingly entered Cornell and followed the regular academic course with the class of 1875, specializing, however, in geology and paleontology.

The collections of Devonian and Cretaceous fossils previously obtained by Hartt in Brazil were assigned to him to work up and resulted in the publication of his first paper: "On the Devonian Brachiopoda of Ereré, Province of Pará, Brazil," in the Bulletin of the Buffalo Society of Natural Sciences for 1874² followed by a "Preliminary Report on the Cretaceous Lamellibranchs Collected in the Vicinity of Pernambuco, Brazil," in the Proceedings of the Boston Society of Natural History for 1874.³

In the preparation of his paper on the Devonian fossils, he spent some time in Albany, New York, where he came under the influence

¹ Reprinted by permission from Science, N. S., Vol. XLVIII, No. 1236, September 6, 1918.

² Vol. 1, pp. 236-261.

³ Vol. 17, pp. 241-256.

of James Hall, the State geologist of the great Empire State; and later while completing the paper on the Cretaceous fossils he studied at the Museum of Comparative Zoology, where he was so fortunate as to be able to attend a course of lectures by the elder Agassiz, then in the last year of his life.

Cambridge proved a congenial environment, and so instead of returning to Cornell, he continued at the Museum of Comparative Zoology from 1873 till 1875, acting also as assistant in zoology at the Boston Society of Natural History. During the summer months of those years he served as volunteer scientific assistant under Spencer F. Baird in the marine explorations of the United States Fish Commission on the New England coast, and thus began his connection with the Smithsonian Institution, for at that time the scientific work of the Fish Commission was practically under the direction of the Smithsonian.

In the autumn of 1875 he received the appointment of geologist to the Geological Commission of Brazil with orders to report to Professor Hartt in Rio de Janeiro, and with that service he continued until March, 1878. His first field work was in the region about the Bay of Bahia, and continued thence down the coast of the province of the same name to near its southern end. Extensive deposits of coal said to occur in parts of that region constituted one of the special objects of the exploration, but the geology was studied in every particular, including the extensive coral reefs that lie along the coast, and also the ethnology of the Indian tribes living inland. The report on the geology and coral reefs was published in the Archives of the National Museum of Rio de Janeiro in 1878.⁴

Later he explored the central and southern parts of the province of São Paulo for the purpose of determining the mineral, and especially the coal, resources, and while these proved to be unimportant, he had the opportunity of studying the origin of the rich red lands where the famous coffee of that region is grown.

On returning to the United States, Mr. Rathbun brought with him complete series of the Devonian and Cretaceous fossils which have since become the property of the United States National Museum. It had been his hope to have monographed this interesting material, but other duties claimed his attention and with the exception of a few papers such as "A List of the Brazilian Echinoderms, with Notes on Their Distribution," which he contributed to the Transactions of the Connecticut Academy of Arts and Sciences for 1879,⁵ the material was worked up by other scientists.

Meanwhile he had accepted from Secretary Baird the appointment of scientific assistant in the United States Fish Commission with

⁴ Vol. 3, pp. 159-183.

⁵ Vol. 5, pp. 139-158.

which service he then continued until 1896. At first the collections of the Fish Commission were preserved in the museum of Yale University in the custody of Prof. A. E. Verrill, to whom he was detailed as assistant, serving also at that time as assistant in zoology at Yale University.

In 1880, owing to the approaching completion of the United States National Museum building, Mr. Rathbun was transferred from New Haven to Washington and brought with him a part of the collections which had been stored at the former place. At that time he was made curator of the department of marine invertebrates in the National Museum, an appointment which he continued to hold until 1914.

As the Fish Commission grew, much of the administrative work was assigned to Mr. Rathbun by Secretary Baird and the responsibility steadily increased until Baird's death in 1887. Meanwhile, although Professor Verrill of Yale was the nominal head of the summer investigations of the Fish Commission, during much of the time Mr. Rathbun had active charge of the laboratories, steamers, and equipment and was responsible for the general management of the work. The collections were mostly assorted under his supervision for distribution to specialists. His own studies at that time related to the commercial fisheries and to the working up of the natural history of several groups of invertebrates.

During 1880 and 1881 he was employed upon the fishery investigations of the Tenth Census and reported on the natural history of, and the fisheries for, the commercial lobsters, crabs, shrimps, corals, and sponges; the marine fishing grounds of North America with the ocean temperatures of the Atlantic coast of the United States. Much of this material appeared in "The Fisheries and Fishery Industries of the United States," which was prepared through the cooperation of the Commissioner of Fisheries and the Superintendent of the Tenth Census under the direction of George Brown Goode. Mr. Rathbun's contributions to these official reports amounted to 550 quarto pages with 106 plates.

Incidental to his work at this period was his association with colleagues in the gathering of material for the Great International Fisheries Exhibition held in London in 1884. He prepared and described the "Collection of Economic Crustaceans, Worms, Echinoderms and Sponges" ⁶ and he was the author of the "Descriptive Catalogue of the Collection illustrating the Scientific Investigation of the Sea and Fresh Waters." ⁷

In 1891, at the request of the Secretary of State, he assisted John W. Foster in preparing material for the United States case at the Paris fur-seal tribunal. He had the services of several experts, and

⁶ Bull. 27, U. S. Nat. Mus., pp. 107-137.

⁷ Idem, pp. 511-622.

was called to report upon the laws of all nations relating to the extralimital fisheries for whales, hair seals, fisheries, precious corals, pearls, beche de mer, etc., and also upon the distribution and habits of these forms. Reports of progress were made daily to Secretary Foster, and the more essential parts of the completed report were incorporated in the extended brief of the American agent.

During the entire period of the fur-seal inquiries Mr. Rathbun was in charge of the investigations, except those of the first international commission. The steamer *Albatross* made yearly trips to Bering Sea with one or more experts, who were directed to study the habits of these animals and to make an annual comparative record of their distribution and numbers by written notes and identical series of photographs. The work was also extended to the Russian islands.

The most important international commission to the fur-seal islands was the one dispatched in 1896. This expedition, with the cooperation of the Secretary of State, was conducted by the Treasury Department. Charles S. Hamlin, then Assistant Secretary of the Treasury, was in immediate charge of the case, and Mr. Rathbun was called to be his chief adviser. The latter was asked to become the head of the American commission, but, declining, was requested to nominate its members, which he did. Mr. Rathbun also prepared the instructions for the commission, which entered into every detail and every accusation on the part of Canada.

In December, 1892, Mr. Rathbun was appointed by President Harrison as the American representative on the joint commission with Great Britain to study the condition of the fisheries in the boundary waters between the United States and Canada and the seacoast waters adjacent to the two countries, and to report such measures as might be deemed necessary to insure the protection of these fisheries. No similar investigation of such magnitude and importance was ever before attempted, and four years were required for its accomplishment. A large party of experts was put in the field on the part of the United States, and Canada assisted to the extent of its facilities. Mr. Rathbun personally visited every point of interest, starting with the Gulf of St. Lawrence, continuing through the fresh-water systems, including the Great Lakes, and ending at Cape Flattery at the west. The report submitted to the Department of State on December 31, 1896, was transmitted by the President to Congress and printed.

It had been Secretary Baird's intention to have Mr. Rathbun transferred to the National Museum, so that he might give his entire time to the development of the department of marine invertebrates and the working up of the important collections that were con-

stantly being received, but on the death of Baird in 1887 Dr. G. Brown Goode, who succeeded temporarily to the office of Fish Commissioner, persuaded Mr. Rathbun, in consequence of his long experience and familiarity with the work, to remain with the commission. Later, when Col. Marshall McDonald became permanent commissioner, he was equally appreciative of Mr. Rathbun's valuable qualities and likewise was able to induce him to remain with the bureau until his own death in 1895.

In 1896, on the invitation of Secretary Langley, he accepted appointment in the Smithsonian Institution, and on January 1, 1897, began his duties as assistant in charge of office and exchanges. Before the expiration of the month his abilities were so manifest and his appreciation of the conditions so complete that he was made assistant secretary. This place he then held until July 1, 1898, when, still continuing as assistant secretary, he was given charge of the National Museum, in which capacity he remained until his death.

It is almost impossible to attempt to consider in detail the many ramifications of the great work that he accomplished, and naturally the minor, but certainly not unimportant, interests are obscured by the larger events to which he gave the later years of his life.

The most important of these was the construction of the new building, in which the natural history collections are preserved. His intense interest in this undertaking, as well as his remarkable capacity for studying details, is perhaps best shown by his careful preliminary study "The United States National Museum: An Account of the Buildings Occupied by the National Collections," that appeared in the annual report of the United States National Museum for 1903.⁸

The years of patient watching and waiting for the completion of the structure, with his perfect knowledge of every detail, can never be satisfactorily told in words, but they are strikingly illustrated by the careful "Descriptive Account of the Natural History Buildings of the United States National Museum" that forms No. 80 of the bulletin series,⁹ that he published in 1913 on the completion of the building.

These two publications show how much he gave of himself to the perfection of a work that must always remain as the greatest monument that can be reared to his painstaking genius.

With an interest equal to that shown by him in the construction of the new Museum building, he undertook the development of the National Gallery of Art, an important feature of the Smithsonian Institution, which, although the one mentioned first in the fundamental act, had remained dormant for lack of adequate facilities.

⁸ Pp. 177-315, pls. 1-29.

⁹ Pp. 1-131, with pls. 1-34.

The valuable collection of painting and art objects bequeathed by Mrs. Harriet Lane Johnston in 1903 to the National Gallery of Art afforded an opportunity quickly appreciated by Mr. Rathbun, who, recognizing its importance, began at once to plan for the building up of a great national art gallery. In 1904 the Freer collection, with its unique specimens of Whistler's art work, was tendered and accepted by the Institution, and in 1907 William T. Evans began his gifts of selected paintings by contemporary American artists, which number more than 150 canvases and an equal number of other art objects. With these and other gifts the National Gallery of Art has "attained a prominence that has brought world-wide recognition." A permanent record of this development has been left by Mr. Rathbun in Bulletin No. 70 of the United States National Museum, under the title of "The National Gallery of Art, Department of Fine Arts of the National Museum,"¹⁰ a volume remarkable for its artistic appearance, to every detail of which he gave his personal attention.

His natural taste for research and his tendency to go to the bottom of things led him to make elaborate studies on the collections, and he has left behind him a valuable series of notes from which the future historians will find little that is lacking concerning the early history of the Museum. At times interesting developments presented themselves, and as typical of those his last important publication may be cited. It was "The Columbian Institute for the Promotion of Arts and Sciences, a Washington society of 1816-1838, which established a museum and botanic garden under Government patronage" (pp. 1-85), which was published as No. 101 of the bulletin series of the National Museum in 1917.

Subsequent to the death of Secretary Langley, in February, 1906, and until the election of his successor a year later, Mr. Rathbun served as acting secretary, and frequently during the absence of Secretary Walcott the guidance of the affairs of the parent-institution was intrusted to Mr. Rathbun as acting secretary.

His bibliography numbers nearly 100 titles, and, in addition to those already mentioned, he was the author of various scientific papers contributed to the serial publications of the Fish Commission and the National Museum, as well as a few biographies of friends and colleagues, such as Charles F. Hartt and Jerome H. Kidder; several popular articles contributed to current literature; and a series of official reports, of which notably those of the National Museum are conspicuous evidences of his patient industry.

Intense devotion to duty was a striking trait of Mr. Rathbun's character, and so, absorbed in the details of his various activities,

¹⁰ First ed., 1909, pp. 1-140, pls. 1-26; 2d ed., 1916, pp. 1-189.

all of which had to do with the institution to which he gave his life, he had but little time for other interests.

Nevertheless, his scientific work gained deserved recognition from Indiana University, which in 1883 conferred upon him the degree of M. S., and in 1894 Bowdoin gave him her doctorate in science.

His colleagues found pleasure in dedicating in his honor recently discovered forms of life, and a genus of fishes, *Rathbunella* ("in recognition of his many services to science"), as well as a genus of starfish, *Rathbunaster* ("in appreciation of his pioneer work on Pacific starfishes"), and many new species of plants, batrachians, fishes, and mollusks preserve his name in the literature of science.

Naturally he was a member of many scientific societies. At home he was active in the Biological Society of Washington, and he was an early member of the Philosophical Society, becoming its president in 1902; also he was a member of the Washington Academy of Sciences, and in 1905 he was chosen by his associates to be president of the Cosmos Club, an honor that he greatly appreciated.

Among the national societies he was a fellow (since 1892) of the American Association for the Advancement of Science, corresponding member of the Boston Society of Natural History, member of the American Society of Naturalists, councilor of the American Association of Museums, and a member of the American Fisheries Society.

His foreign connections included membership in the Fisheries Society of Finland, the Russian Imperial Society for the Acclimatization of Animals and Plants, and corresponding membership since 1917 in the Zoological Society of London.

Mr. Rathbun was also a permanent councilor of the International Fisheries Congress, a member of the American committee for the Boston meeting of the International Zoological Congress, and in recent years every gathering of scientists, such as the International Congress of Applied Chemistry, the International Congress of Americanists, and the Second Pan American Scientific Congress held in Washington, placed his name on their honor lists of distinguished members.

At a memorial meeting of the various members of the staff of the Smithsonian Institution and its branches, held in the National Museum on the day of Mr. Rathbun's death and presided over by Mr. Henry White, a regent of the institution, record was made of "their profound sorrow at the loss of a sincere friend, an executive officer of marked ability, and one whose administration has had a wide influence upon the scientific institutions of the Nation."

A GREAT CHEMIST: SIR WILLIAM RAMSAY.¹

By CH. MOUREU.

Although the progress of science is continuous, it is neither uniform nor regular. From time to time this progress is suddenly accelerated, leaving strewn along the route the successive bounds, and creating thus a sort of discontinuity in the continuity. These sudden forward leaps are the work of a small number of geniuses whose discoveries guide the countless efforts of experimenters. When Dalton conceived the atomic hypothesis, he opened up and made fertile the entire domain of chemistry. When Davy isolated the alkaline metals he revealed to astonished chemists a whole new world. The idea of chemical function, the law of substitution, the law of the homology, the atomic theory, are fundamental additions to knowledge derived from the works of Dumas, Laurent, and Gerhardt, who have transformed and rejuvenated chemistry, opening to it wider horizons. In opening synthesis as a channel for organic chemistry, Berthelot rolled back its frontiers immeasurably. It is in the ranks of these great chemists, worthy followers of Lavoisier and of Priestley, that belongs the brilliant investigator, the fertile inventor, the hardy pioneer whose work, so deeply original, and whose powerful personality, the counselor of the Chemical Society has given me the flattering mission of reviewing before you.

The name of Sir William Ramsay calls to mind at once, with all their meaning, two capital discoveries, to some extent paradoxical: On the one hand, the existence in the atmospheric air of a series of gaseous elements, which their chemical inertness relegates to the very borderland of chemistry; on the other hand, the production of one of these gases, helium, by the spontaneous disintegration of the radium atom, two classes of facts essentially new and of fundamental importance, whose discovery was possible only to an investigator of the highest rank, capable through exceptional ability, natural or acquired, of bringing light into the darkness of the unknown.

Of Scotch origin—he was born in Glasgow in 1852—Ramsay's hereditary influences were most favorable. In his family were chemists and doctors of note, and one of his uncles, Sir Andrew Ramsay, was a well-known geologist. Thus, as he himself liked to recall, Ram-

¹ Translated by permission from *Revue Scientifique*, October, 1919.

say was descended from ancestors well above the average intellectually and in scientific pursuits, and he was well aware that he owed to them his calling and his ability as a chemist.

Having begun his studies in his native city, Ramsay went to complete them in Germany, at first at Heidelberg, with Bunsen, and afterwards in Tübingen in the Fittig laboratory, where after some researches on the ammonia compounds of platinum, he studied the toluic acids. Organic chemistry attracted him by the flexibility of its combinations and the ingeniousness of its structural theories. On his return to Glasgow, where he secured a post as assistant, he studied specially the pyridic group, doubtless attracted by the problem of the synthesis of the cinchona alkaloids. Let us recall the synthesis of pyridine itself by the direct union of cyanhydric acid with acetylene, the production of the different pyridinic acids by the oxidation of the bases of Anderson, the production of the same acids (in collaboration with Dolbie) from quinine, from cinchonine, etc., an important observation which directly related these alkaloids to pyridine.

In 1880, at the age of 28, given the title of professor of chemistry at the University of Bristol, Ramsay began, in collaboration with his assistant, S. Young, a series of works on physicochemistry which were not slow in being noticed. They had for an object the revision of the physicochemical properties of a certain number of liquid types, water, alcohols, ethers, hydrocarbons, etc., with a view especially of determining exactly the relation of these properties to the atomic or molecular weights. A vast field was thus explored: the densities of steam, the tensions of steam, thermic constants, dissociation, critical points were studied and many new and interesting observations were made. For the execution of so many delicate researches, all kinds of new apparatus had to be designed and constructed, with the result, extremely fortunate for the following of his career, that Ramsay became a very adroit blower of glass. Many of these contrivances are to-day in every-day use in laboratories.

It was in 1887 that Ramsay was called to the University College at London, to succeed Williamson in that chair of chemistry already renowned, which he was by his efforts to make shine with a great light. For 30 years in fact, Ramsay was to display in this post of honor the most fertile and brilliant activity. His peculiar qualities as an experimenter and his originality stood out in striking relief in a work which he published in 1893 in collaboration with Shields. Following a remarkable series of researches on surface tensions and densities at different temperatures, Ramsay gave to science the first experimental method of determining the molecular weights of substances in a liquid state.

We will leave here various other works, of a special nature, in order to come without more delay to those researches which were to immortalize the name of Ramsay.

In 1894 Ramsay was 42 years of age. His work was already considerable in amount and his reputation solidly established, but he could not yet be called a celebrity. In possession of scientific knowledge as profound as it was extensive and varied, a penetrating mind with broad vision, a philosopher mindful of the general movement of the sciences, and eager to solve the mysteries of nature, free from all dogmatism and with mind open to even the most daring conceptions, an experimenter of finished technique, an enthusiastic spirit, Ramsay was ready for epoch-making discoveries. Given a favorable occasion, his genius would be fully equal to the task. Here is the occasion.

As often happens in scientific research, a chance observation may lead to the most unexpected results. Lord Rayleigh, who for several years had pursued with meticulous care the determination of the density of the principal simple gases (hydrogen, oxygen, nitrogen), noticed that the density of the nitrogen extracted from the air through absorption by other known gases was always greater than that of chemical nitrogen, coming from different sources—oxides of nitrogen, ammonia, urea, etc. The difference affected the third decimal and did not exceed one-half per cent, but it was certainly more than experimental error.

Three hypotheses could explain this irregularity. The atmospheric nitrogen might be constituted in part of complex molecules of nitrogen comparable to the oxygen compound called ozone. Conversely, in the chemical nitrogen a certain proportion of the molecules might be dissociated into free atoms. But the density of neither of the gases, after being kept for eight months, underwent any change, and the permanent existence of condensed nitrogen or of dissociated nitrogen (atomic nitrogen) would scarcely be likely. Lord Rayleigh, who had at first accepted these explanations, rejected them to adopt the third hypothesis, according to which the atmospheric nitrogen is constituted of a chemical nitrogen mixed with an unknown gas of greater density. Being consulted by Lord Rayleigh, Ramsay was of the same opinion, and the two scholars at once united their efforts to isolate the mysterious gas whose existence was thus revealed.

It is interesting to recall here that in the fundamental experiments in which Cavendish, a century before, had established the formation of nitric acid by the prolonged action of electric sparks on a mixture of oxygen and nitrogen in moisture, the celebrated English chemist had noted that even after a very long time there always remained after absorption of the oxygen in excess a small gaseous residue rep-

representing about one one-hundred-and-twentieth of the volume of nitrogen. But the observation had passed unnoticed, and until the researches of Lord Rayleigh, the nitrogen in the air had been considered as a simple gas, identical with "chemical nitrogen."

While Lord Rayleigh, taking up again the experiments of Cavendish, verified the fact that atmospheric nitrogen does indeed leave, after the action of the oxygen and the spark, a residue which could not be overlooked, Ramsay attacked the problem by a purely chemical method, that of absorbing the nitrogen by magnesium at red heat. The repeated action of this metal increased the density of the gas. From 14, its weight in relation to hydrogen, the density increased little by little to become fixed in the neighborhood of 20. What remained was a new gas, absolutely distinct from nitrogen, characterized, aside from its density, by a peculiar spectrum very rich in lines in all regions and, a fact without precedent, by absolutely no ability to combine with any other substance whatsoever.

At the British Association meeting at Oxford in 1894, at the memorable session of August 13, Lord Rayleigh and Ramsay announced in turn that the nitrogen of the air is not pure nitrogen, and that it contains a small proportion of a gas more dense and much more inert, to which they gave, on account of its chemical inertness, the name of argon (α priv.; $\epsilon\rho\gamma\sigma$, energy). This communication caused a great sensation among the audience, and the daily press took up the matter at length.

But chemists are generally conservative, and although the discovery was affirmed by two scholars so well qualified, many remained incredulous. It was not certain that argon was a simple substance. The molecular weight, according to the density, being 40, it might be a form of nitrogen cyanide CN_2 ; it was noticed also that a triatomic molecule of nitrogen N_3 would have a weight of 42, a figure not far from the one given above.

A few months sufficed for Ramsay to clear up the question and dissipate all doubts. The comparison of the specific heats at a constant volume and at constant pressure shows an equally unexpected fact—that the molecule is monatomic, and consequently the new gas can only be an element.

There is never anything fundamentally new except that which could not be foreseen; that which is foreseen is implicitly contained, like the corollaries of a theorem, in that which is already within the domain of knowledge. To find in the air a new gas, and, in addition, one of absolute chemical inertness, is indeed a truly great discovery. It brought at once to the authors a deservedly great renown. Ramsay was not slow in adding to it through other researches not less surprising. And it was here again that a fortunate

opportunity presented itself to him; he exploited it with admirable and masterful decision.

Early in 1895 Ramsay learned, through a letter from Sir Henry Miers, that Hillebrand, chemist in the United States Geological Survey, had observed, while treating a uraniferous mineral, cleveite, with boiling sulphuric acid, the giving off of a gas which appeared to him to be nitrogen. The effect produced on Ramsay by this news was entirely characteristic of his scientific temperament. Many chemists, while finding the observation interesting, would have put off the study of the subject until later, when they might have more leisure. Ramsay, on receipt of the letter from Sir Henry Miers, called the laboratory aid and dispatched him immediately to the shops of the mineral merchants of London to buy all the cleveite that he could find. The cleveite arrived toward noon; before night it had been treated and the gas collected. During the two following days the known gases, except argon, which it had been expected would be found, were eliminated and the residue introduced into a spectrum tube. The spectrum of argon was not observed. There were few lines; one of these—yellow—was very brilliant. It was thought at first to be the line of sodium, present, perhaps, in the corroded electrodes. But Ramsay laughed at the idea; he was not in the habit of using dirty spectrum tubes, and, besides, he had made the tube himself. A comparison spectrum of sodium was observed simultaneously. The two lines were distinct and in no way superposed. It was then beyond doubt that it was a new gas, and the hypothesis was advanced that it might be helium.

Helium was that element, still unknown on the earth, whose existence in the sun was known through a spectroscopic observation carried out by the French astronomer Janssen at the time of the solar eclipse of the year 1868, and the subsequent suggestions of the English physicists Frankland and Lockyer. Was this new gas of Ramsay's helium, or was it not? The answer was not long in coming. The spectrum tube was sent to Sir William Crookes, who measured with great care the wave length of the yellow line and found it identical with that of the solar line of helium. Scarcely a week had passed since Ramsay had received the letter from Sir Henry Miers.

At the general reunion of the Chemical Society in March, 1895, the discovery of terrestrial helium in the gases from cleveite was announced. Its molecular weight was 4, and a study of the specific heat indicated that the molecule was monatomic, like that of argon, which it also resembled through its complete chemical inertness.

During the two following years Ramsay hunted carefully for other sources of argon and helium. Argon and helium were found in certain mineral waters, those of Cauterets among others; to-day

we know that they exist in all subterranean waters and gases.² Furthermore, helium can be derived from a series of rare minerals; this observation was of great interest in what followed, after it was discovered that the same gas was given off in the disintegration of radium, as we shall see later on.

Their resistance to any combination assigned to argon and helium a place apart among the elements, and they did not fit in any of the groups of Mendeleeff's table. Ramsay boldly suggested that they constituted the first two known terms of a new group, characterized by a valence of zero. Secure in observed analogies in the other groups of the periodic system, Ramsay, in a communication to the meeting of the British Association in Toronto in 1897 with the suggestive title, "An Undiscovered Gas," predicted the existence of at least one other inert element, situated between helium and argon, near fluorine and having an atomic weight not far from 20.

Before another year had passed, not only had Ramsay's prediction been realized, but more, in collaboration with Morris Travers, two other elementary inert gases had been discovered, whose places he also fixed in the periodic system, near bromine and iodine, with the neighboring atomic weights of 82 and 130.

Ramsay submitted to a close examination different thermal waters, such as those of minerals and of meteorites, without being able to discover any of the gases which he sought. Their presence in all the subterranean gases was to be demonstrated later,³ thanks to the use of a method of fractionating by means of cooled charcoal inaugurated by Sir James Dewar.⁴

But if the three gases to be discovered really existed, ought they not to be found in considerable proportion in the atmospheric nitrogen along with argon?

One hundred cubic centimeters of liquid air having been reduced through spontaneous evaporation to several cubic centimeters, Ramsay vaporized them in a gasometer, then eliminated from it the oxygen and nitrogen by appropriate means. The gaseous residue thus prepared furnished the spectrum of argon with, in addition, a yellow line and a very brilliant green line. Besides, the density was a little greater than that of pure argon; the residue examined was then argon mixed with a certain proportion of a heavier gas.

In order to isolate this gas, Ramsay aided by Travers, prepared 15 liters of argon, a task requiring several months, and liquified it by

² Charles Moureu, "Recherches sur les gaz rares des sources thermales; leurs enseignements concernant la radioactivité et la physique du globe," *Journal de Chimie physique*, t. 11, no. 1, p. 63-152, 1913. Charles Moureu and Adolph Lepape, "Les gaz rares des Grisous," *Annales de Chimie*, 9^e s., t. 4 et 5, 1915-1916.

³ Charles Moureu and Adolphe Lepape, *loc. cit.*

⁴ Separation directe, sans lignéfaction, des gaz les plus volatils de l'air (*Ann. Chim. Phys.* 8^e serie, t. 3, p. 12; 1904).

cooling with liquid air. The clear liquid obtained was submitted to a fractional evaporation very skillfully conducted, with the purpose of separating the gases more or less volatile than argon. The success was complete.

The first breaking up furnished a light gas, about ten times more dense than hydrogen, and characterized by a magnificent spectrum with brilliant lines in the red and the yellow. Ramsay called it neon. It is moreover accompanied by a certain proportion of helium, present also in the air, and from which it can be separated by the use of liquid hydrogen (-253°), which solidifies the neon and leaves the helium in a gaseous state.

The end products of the distillation of liquified argon retained the two other new gases, which could however be separated by liquifaction and fractionating. Ramsay called them crypton and xenon; their densities in relation to hydrogen were 41 and 65.

For the three new gases, neon, crypton, and xenon, the study of the specific heats led, as for helium and argon, to a monatomic molecule. They are likewise chemically inert. Their atomic weights 20, 82, and 130 were found to occupy exactly the places indicated by the classification of Mendeleeff.

Thus, in the atmospheric air, which during more than a century had been believed to be perfectly known, Ramsay had succeeded in the four years from 1894 to 1898, in isolating a complete natural group of simple gases. Indeed a splendid achievement. Striking proof of the fundamental truth comprehended in the periodic law. Witness, just as noteworthy, of the scientific faith and the ability in experimentation of this master. Nearly all the apparatus had to be invented, and Ramsay also had to construct most of it himself. Only those who have handled small quantities of gas and have prepared absolutely pure gases, giving spectra entirely free from foreign lines, are able to understand all the technical difficulties of such a work.

A little before the discovery of crypton, Ramsay thought he had isolated another element in the atmospheric argon; it had the same density as argon, but its spectrum was entirely different; he called it metargon and described several principal lines. Metargon was not, however, a new element; it was recognized that the lines indicated were due to traces of carbonic oxide, which occurs as an impurity in argon. Other chemists were working on the same problem, and Ramsay, too much hurried, had insufficiently purified his argon. I will cite Ramsay himself in this connection:

Should we under such circumstances regret the publication of an error? It seems to me that an occasional error should be excusable. No one can be infallible; and besides, in these conjectures one has always a large number of good friends who promptly correct the inaccuracy.

It is certain that anyone may be deceived; but it is not anyone indeed who would have been capable of discovering crypton and xenon in the air, which contains in volume 1 in 20,000,000 of the first and 1 in 170,000,000 of the second.

This research on the rare gases of the atmosphere will remain a perfect model of original research. And if there was anything to be admired more than the ability in experimentation and the scientific penetration displayed, it was the energy and persevering ardor, qualities doubtless less brilliant, but which in this kind of work were absolutely indispensable.

Another question, in this connection, could not fail to present itself to Ramsay's mind. Are there not in the same group of inert gases, noble gases, as he liked to call them, other elements, heavier than xenon as predicted by the periodic system, or lighter than helium, such as nebulium, whose presence is probable in the nebulae, and coronium, which appears to exist in the solar corona?

We will recall in passing that beside the inert gases, Armand Gautier recognized in the atmospheric air an appreciable proportion of a gas lighter than helium and which was not other than hydrogen, whose production proposed a most suggestive geochemical problem.

Ramsay busied himself then in the search for new rare gases. With Watson he examined the lightest gases in the atmosphere in the hope of obtaining a gas less dense than helium, but without success. He was not more fortunate in the systematic study, undertaken with Richard Moore, of the distillation products of an enormous mass of liquid air (120 tons), put at his disposal by George Claude. Ramsay arrived at the conclusion that if the air contains gases heavier than xenon, the proportion of them is extremely small and does not exceed one twenty-fifth of one-billionth.

The discovery of the rare gases had excited universal enthusiasm. Physicists and chemists far and near wished to study these new elements; and it is interesting, for the glory of Ramsay, to indicate briefly the principal results that have issued from this study.

Some, interested especially in the problem of affinity, sought, but in vain, to arouse chemical activity which they supposed to be dormant in the rare gases.⁵ Others, on the other hand, sought for them in natural media. Following a systematic study of a great number of subterranean gases (gas from thermo-mineral sources, volcanic gas, fire-damp), some simple conclusions have been formulated:⁶

(1) All the natural gaseous compounds contain the five rare gases, and certain of them contain appreciable quantities of helium, some as much as 6 per cent (thermal gas of Maizières, Côte-d'Or), and even 10

⁵ Troost and Ouvrard, C. R., t. 121, p. 394; 1895. Berthelot, C. R., t. 120, pp. 581-660 and 316, 1895; t. 124, p. 113, 1897.

⁶ Charles Moureu and Adolphe Lepape, *loc. cit.*

per cent (thermal gas of Santenay, Côte-d'Or). (2) The quantitative relation crypton-argon has practically the same value in all natural mixtures, the atmospheric air included; the relation crypton-xenon, different from the preceding, is likewise constant, as is also the relation xenon-argon, and as also appear the relations of these three gases with neon; it is possible to explain the constancy of the relations by the chemical inertness and the analogous properties of these gases, which have thus been able, since the time of the original nebulae, to come through free and mixed together and without their quantitative relations being sensibly changed, all the cataclysms of astronomy and geology. (3) Helium, it is true, accompanies the other members of the group on all their voyages, but it escapes all proportionality; and it could not be otherwise, inasmuch as only helium is produced continually from radioactive substances, and these are unequally divided in the different strata.

You see, gentlemen, what unexpected and weighty problems have been brought up by Ramsay's discovery. What an exceptional destiny is that of these five gases, whose chemical inertness has assured to them, since the beginning of time, an eternal inviolability, and has thus made of them, like the demigods, immortal witnesses of all the physical phenomena of the earth and of the evolution of the spheres!

For what practical applications are the new elements destined? Lighting tests in neon have proved very encouraging. Argon is used in incandescent lamps. And above all—Ramsay himself made the proposition—balloons have been inflated with helium, and by this means made noninflammable.⁷

What a prospect for aeronautics! How far we are from the famous solar spectrum line of Janssen, found again by Ramsay in the gas from cleveite! Other uses will follow for helium as well as for the related gases; their career is still only at the beginning. New example, among a thousand, of the value of purely speculative research! All scientific discoveries, however exclusively contemplative their concern at first might appear, can not fail to lead sooner or later to practical applications. Would that the directors of our affairs could realize this fact which carries with it so much benefit and so much hope, and which also holds for them duties and responsibilities in the eyes of the country which has put its future in their hands. Could they but understand that science is power, that science is wealth! Let them encourage, with all their power, scientific research. Let them understand that learned men can not live differently from other men, and that they also have the right to a normal and honorable existence. Let them generously endow laboratories. Let them grant means for specially interesting studies which may be

⁷ Cottrell, "Fabrication industrielle de l'hélium," *Chimie et Industrie*, 1919.

indicated to them. Let them take under their protection the young men of talent whose gifts should belong to the Nation, and whose development would bring to it glory and prosperity. Let them be able, in a word, to see in the budget for science a productive expenditure, a veritable investment with large returns. Then will they assure to research workers the means for their study, to learned men the possibility of giving their lives to science.

We now come to the year 1902. Pierre Curie and Mme. Curie had just obtained radium, the magnificent completion of an admirable work begun by Mme. Curie in 1897, a little after the discovery of radioactivity by Henri Becquerel in 1896. It was a logical outcome that Ramsay was attracted toward these most interesting researches. The new domain thus opened to science had as yet been explored only by physicists; it seemed to him immediately that chemistry also could and ought to enter on the scene. He entered boldly on the subject; he was to make conquests in it of vast importance.

Frederick Soddy had come from Montreal, where he had been assisting Sir Ernest Rutherford in his beautiful work on thorium. The curious fact had been discovered that a material substance was continually given off from thorium; it was given the name of emanation. Actinium and radium also gave off an emanation. These new substances were evidently of a gaseous nature; and, with all the skill already acquired in the manipulation of small quantities of a gas, Ramsay found himself very well fitted to make a study of them. In collaboration with Soddy he tried to obtain the spectrum of the emanation of radium. As the amount of emanation which comes from even a relatively large quantity of radium is extremely small it was necessary to devise a special spectrum tube. It consisted of a thermometric capillary tube with an electrode made of a platinum wire soldered at the end, the second electrode being mercury, which was put in in advance with the very small quantity of emanation with the aid of a pump. Traces of impurities prevented seeing the spectrum of the emanation which it was not expected to see until later; but what was the surprise of Ramsay and Soddy when, after the passage of sparks through the gas for some time, they saw appear, little by little, the lines of helium!

Helium! Still helium, a kind of *leit motiv* in the scientific life of Ramsay. And an element produced by another element! The magnitude of the discovery immediately appeared. For the first time was beheld the transmutation of one element to another! It was entirely revolutionary. Is it necessary to add that the scientific public did not at first believe and that it would continue to doubt for a long time? The helium had come from anywhere except from the emanation: From the glass, from the mercury, from the platinum, from the walls of the pump. Was not the indestructibility of atoms the dogma

of dogmas? Since the time of the alchemists no one has believed in transmutation. Transmutation was the most extravagant of utopias. And yet to-day, but a few years later, who doubts that the atom has contradicted its etymology and disowned its name? Who doubts that the atom of radium disintegrates spontaneously and that the emanation and helium are the products of this disintegration? Who doubts that there is a complete genealogy of radium, going from uranium to lead, and that the differences in mass are due definitely to the expulsion of particles of helium gas thrown out like ballast in order to lighten the atoms for the beginning of a new existence? Who doubts finally, since the beautiful work of Sir J. J. Thomson, Sir E. Rutherford, and some other physicists, that the atom with its electrons and other constituent elements, is a very complicated organism, in fact, an entire world? It is no use for people to erect barriers between the known and the unknown; they will fall some day under the continuous pressure of original research; and happily there are many that have already thus been overturned on the paths of science.

The discovery of Ramsay and Soddy was not slow in being taken up; the formation of helium was demonstrated as coming from actinium by Debierne, from thorium and uranium by Soddy, from polonium by Mme. Curie and Debierne, and from ionium by Boltwood.

It is fitting to recall, before leaving this subject, that Rutherford had previously expressed the idea that the particles "given off by the radioactive elements ought to be made up of atoms of helium."

This destruction of radioactive atoms, in which Ramsay was the first to see born helium atoms, had the effect of liberating an enormous quantity of energy, capable of effecting immediately varied chemical reactions—the breaking up of water, of carbonic gas, of hydrochloric acid gas, of ammonia gas, of the substance of glass, etc. The emanation from radium, in its disintegration, gives off for each cubic centimeter a quantity of heat equal to that furnished by the explosion of $3\frac{1}{2}$ cubic meters of the explosive mixture of oxygen and hydrogen gases. Ramsay supposed that if a sufficient amount of emanation of radium was put in actual contact with atoms, the energy liberated by the decomposition of the emanation would be able to break off some of them. In common with Cameron, he announced that he had thus obtained lithium, starting with copper, and carbon, starting with thorium and other elements of the same group. There has been and still is a great deal of skepticism regarding these transmutations. Mme. Curie and Mlle. Gledisch having repeated the experiments with copper, the results were negative. On the other hand, Ramsay carried out experiments without the use of emanation and they gave no trace of lithium. Continued researches ought to settle the debate.

The experiments of Ramsay and Cameron had been carried out on aqueous solutions of metallic salts. In the case of copper, the gases derived from the liquid after the elimination of the oxygen and hydrogen coming from the decomposition of the water, gave the spectrum of argon, without any line of helium. On the other hand, in treating distilled water with the emanation, neon was obtained, with a trace of helium, but no argon. These results also were contested.

Ramsay, being asked one day by Richard Moore if he would try the experiments again, made a typical response: "No," he said, "I do not believe it worth while. I can only find again lithium and neon, and for me to obtain the same results again would not be a confirmation. I will leave to others the task of repeating the researches."

The extreme interest of the subject led him to expect that new studies would be undertaken by skilled experimenters having at their disposal sufficient quantities of radium.

Another problem, in some degree the reciprocal of the preceding, naturally presented itself: If the disintegration of heavy elements can lead to light elements, would it not be possible, by an inverse method, to condense light atoms into heavy atoms and thus realize in all its fullness the dream of the alchemists? Ramsay was not afraid to take up the subject. Collie and Patterson, having submitted the glass of an ordinary empty tube to cathodic bombardment, had announced the production of helium, which had been formed by the condensation of four atoms of hydrogen. Ramsay confirmed this result, and, going further, found that if the hydrogen is moist—that is, if it is accompanied by oxygen—there will be, moreover, formation of neon, created by the addition of the atom of helium (4) to the atom of oxygen (16). It seemed to him, therefore, that under analogous conditions sulphur would lead to argon and selenium to crypton.

Here, as well, the question should be taken up again. Its breadth, perhaps, surpasses that of all the others. Ramsay will have the honor of having opened up the new field, thanks to his incomparable talent in experimentation, as well as to his boldness and the independence of his scientific conceptions.

These are, in fact, Ramsay's most pronounced characteristics. They are shown again, and in a most brilliant manner, in another work on the radium emanation which he carried out in 1910 with the assistance of Whitlaw Gray. According to the theory of disintegration, the atom of emanation results from the loss of a helium atom by an atom of radium. If the atomic weight of radium is 226 and that of helium 4, the weight of an atom of emanation ought theoretically to be 222. Emanation, whose resistance to all combination had, moreover, been shown, came thus to occupy in the column of rare gases in

the periodic system the place predicted for a homolog of xenon. Ramsay wished to prove this by experiment. And what an experiment! The volume of emanation at his disposal at any one time never exceeded five one-thousandths of a cubic millimeter (much less than the smallest head of a pin), and to determine the atomic weight it was necessary to weigh this infinitesimal volume of gas. A modification of the microbalance of Steel and Grant was constructed, whose sensitiveness attained several millionths of a milligram. The skill shown in preparing, purifying, and weighing the minute quantities of emanation was truly wonderful; and it was this work more than all the others which showed Ramsay's marvelous experimental talent. The result justified the effort. The mean of five determinations gave the number 223 for the atomic weight of radium emanation. A full and complete verification of the theoretical predictions, which Debierne also confirmed by an entirely different method (diffusion)

The brilliance of his work had brought to Ramsay the highest distinctions not only in his own country but all over the world. Academies and learned societies hastened to open their ranks to him. Our Academy of Sciences, which had elected him a correspondent in 1895, named him an associate in 1910. He was also an associate member of our Academy of Medicine. In the year 1904, the Academy of Stockholm awarded him the Nobel prize in chemistry.

One of the characteristic traits of Ramsay's personality was his enthusiasm, which he communicated to all those who worked under his direction, and the impression which he produced on his students, even during a very brief contact, remained ineffaceable. Friendly and patient with all, to "do well," according to his own expression, was all that was necessary to become his friend.

Ramsay was a remarkable teacher with an elegant and picturesque manner of expressing himself, impulsive, clear, concise, and with the great charm of simplicity. In his lessons he did not hesitate at times to use the most advanced teachings; he was the first in England to introduce the works of Raoult, Arrhenius, and Van't Hoff.

Everything which lives is in a progress of evolution. The real life of an experimental science like chemistry is in progress and discovery. On this subject, Ramsay was of the opinion that he wanted original research to occupy early as great a place as possible in the work of a student. He distrusted examinations such as are usually held to judge candidates, which were too often dependent on chance. He feared especially that they might result in unjust and unfortunate eliminations capable of discouraging a student in his choice of a vocation. The professor who has followed the student during several years in the course and especially in the labor-

atory seemed to him to be better fitted than anyone to appreciate his true value. Ramsay always forcefully maintained these ideas and their logical consequences. The fact is, although, to be sure, other factors enter into it, that the future of science depends in a large part on the scientific aptitude of those who cultivate it. The choice of future scholars—and by this word we mean principally the future masters, the future leaders—takes on, then, a capital importance. Great then is the responsibility of those who have charge of making this necessary selection. They ought to realize the essential fact that knowledge is good but power is better. Far be it from us indeed to deny the utility of much learning, of being well posted in every subject, as are the very learned; but this would be sterile and encumbering from the point of view of original research, sole source of progress, if there were lacking to exploit it a clear intellect, a sure judgment, and that ensemble of qualities which constitutes what is called “*esprit de finesse*.” The true scholar, the real originator of scientific progress, is not the one who knows, it is the one who acts, who creates. “Better,” Montaigne has said, “a good brain than a full brain.” The former has that which is called potentiality, latent force, virtual power, productive, and creative energy, which allows it on occasions to accomplish original work; the latter, in the absence of these necessary gifts, would have access only to the domains already largely explored, where it would, however, still be able to do useful work. Both have their places to fill; but the general welfare as well as the interest of the specialist demands that each be in his place—“the right man in the right place.” To keep this ideal in view ought to be the constant thought of those on whom has devolved the difficult rôle of arbiters.

In our time of general reorganization, when all institutions and all methods are undergoing revision, it is to be regretted that the great voice of Ramsay is not more listened to in this important matter of teaching.

Ramsay wrote but few didactic works. His little treatise on “Modern Chemistry,” which has been translated into French, is a brief but substantial account of the principles of chemical philosophy. The same qualities are found in the highest degree in all Ramsay’s writings. They are noted especially in several dissertations in which he developed his own ideas, and whose titles alone are enough to indicate their originality: “The Electron Considered as an Element,” “Element and Energy,” “Helium in Nature,” “Problems Presented by Inorganic Chemistry,” etc.

Ramsay was a polyglot and spoke fluently French and German. At the International Congress of Applied Chemistry held in Rome in 1906 he gave in French a lecture on “The Purification of Drain

Water," a subject far enough away from the matters of pure science with which he was supposed to be entirely occupied.

He came willingly into our country. He loved it and counted there many friends who have many charming letters from him full of a natural simplicity. We have also the remembrance of the excellent lectures which he gave here on his discoveries.

Before the war he had also many connections in Germany and was there the object of many flattering attentions. During the celebration of the centenary of the University of Berlin in 1910 the delegates of the universities of the whole world were invited for the principal ceremony. Ramsay represented the University of London. When the Kaiser entered the room with his whole following, having perceived Ramsay, he stopped the cortege and went out of his way to take his hand.

"The soul of Ramsay," our colleague, Paul Sabatier, wrote in a beautiful study which he has consecrated to him, "the soul of Ramsay could not be conquered by such homage, and in many circumstances before the war where I have been able to see him from near by, I have been sure of his deep distrust of Germany and of its inordinate ambitions." This testimony can be completed by the well-known fact that Ramsay was one of the most resolute partisans of the "Entente Cordiale."

German science, which he had seen at first hand, had never impressed him, and he passed on it the severest judgment. In the fine response which he addressed in October, 1914, to the manifesto of 93 German scholars, these lines are found: "* * * Some German individuals have attained the highest summits and merit universal admiration. But in spite of these brilliant exceptions, it can be said that originality has never been the characteristic of the German race; their special function has been to exploit inventions and to put to work the discoveries of others * * *;" and further, facing the necessary hypothesis of the complete destruction which the German power ought to suffer for the security of the world, he added: "* * * Would the progress of science be retarded? I do not think so. The greatest works in scientific thought are not due to representatives of the Germanic race; moreover, the early applications of science do not come from them. As far as we are able to perceive, it seems that a restrictive measure on their activities would only have the effect of delivering the world from a deluge of mediocrities." At the beginning of the war, during the tragic days of 1914, Ramsay was at Havre, where he attended with Lady Ramsay and his son the congress of the French Association for the Advancement of Science, presided over by M. Armand Gautier. He delivered a discourse at the opening session and was present at the

first session of the section of chemistry. But, visibly, his thought was absent. The news became each day more alarming. After Wednesday, the 29th, when he perceived war imminent, as fixed in the criminal plan of Germany, he was not seen again at the Congress.

Ramsay saw immediately all the import and how much was at stake in the formidable conflict. Civilization, once more in a struggle with barbarity, had to repulse the most redoubtable assault she had ever withstood. It was necessary to conquer or submit to enslavement.

From the beginning of hostilities, Ramsay, with his ardent patriotism, threw himself into the conflict. He fought with all the means in his power, through research in the laboratory and through his original suggestions, by pen and word, which he made the auxiliaries of his most indisputable authority. Of him also could be employed the famous phrase, "*Je fais la guerre.*" It was through his persevering efforts chiefly that cotton was, too late perhaps, declared contraband of war. He died in full activity, 63 years old, while his genius was still so rich in promise for science and for humanity, brought down by an incurable disease that carried him off in a few months. Our unanimous regret is that the great joy was not given him of assisting in the complete victory of the Allies, a victory which he believed in implicitly, and also with all the ardor of his faith in the destinies of our immortal countries, and in the final triumph of morality over crime, of incontestible right over brute force.

The premature death of Ramsay is for science an irreparable loss. In his loss a powerful beacon light is extinguished. This great investigator explored chemistry as a conqueror, and the progress which it owes to him are the strides of a giant. Ramsay served and was an honor to humanity, and he has brought to his native land incomparable renown. He was great not only in his genius and scientific enthusiasm, but also in the elevation of his soul, absorbed in the ideal, and in the greatness of his character. He will live in the memory of mankind, and posterity will keep aloft the name of Ramsay.

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N.C

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